THE STEREOSCOPE IN OPHTHALMOLOGY

DAVID W. WELLS, M.D., F.A.C.S.

THE STEREOSCOPE IN OPHTHALMOLOGY

WITH ESPECIAL REFERENCE TO THE

TREATMENT OF HETEROPHORIA AND HETEROTROPIA

Designed to Accompany the Phoro-Optometer Stereoscope and the Wells Selection of Stereoscopic Charts

BY

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hoping that others would follow the example so that one might be able to decide the relative value of different methods. Until this is done it is impossible for the earnest truth seeker to decide which of the various methods of advancement is the best. In this series the greatest effect of one operation without tenotomy was 30°; more often 15° to 20°. This variation is mentioned by Landolt and Meller.

Landolt says: *"No true clinician attempts to determine the effect of a muscular operation with mathematical accuracy, for in addition to the variations in the insertion and the degree of shortening of a muscle, the action on the eyeball must be considered from still a number of standpoints. It is therefore not possible to say that the tenotomy, or the advancement or the shortening of a muscle, causes a change in the direction of the eye of so and so many degrees, nor does the degrees of deviation of the eye necessarily give the degree of resection or advancement of the muscle which is necessary for its correction."

*Archives of Ophthalmology

PREFACE.

CONCERNING the clinical importance of heterophoria ophthalmologists are not agreed. As a protest against the extravagant claims made by some enthusiasts, there has arisen a class of eminent practitioners whose members absolutely ignore the subject, and omit all tests for imbalance, unless there exists actual heterotropia. The author believes he occupies a middle ground, and that the opinions herein expressed are conservative.

The orthoptic treatment of heterotropia is not always successful, but there is a growing conviction that the surgeon who rests content with securing a cosmetic cure has not discharged his whole duty to his patient.

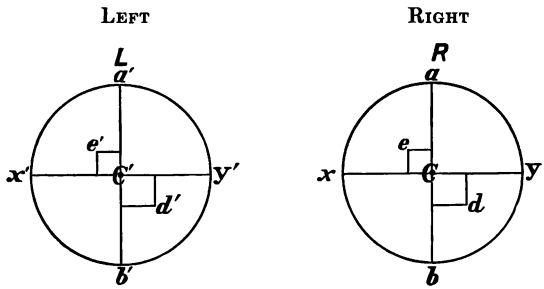
It is unfortunately still true that the majority of heterotropic cases are not seen by the ophthalmologist until the condition is quite firmly established. No opportunity should be lost to warn the family physician that the time to begin treatment is the minute the deviation is noticed.

Believing that the cases of heterophoria requiring relief are much more numerous than those of actual heterotropia, the greater

CHAPTER I.

BINOCULAR VISION. — LAW OF CORRESPONDING POINTS. — SEMI-DECUSSATION. — FUSION FACULTY. — THE HOLMES STEREOSCOPE.

BINOCULAR single vision is a rather intricate psychic faculty, dependent on certain exact physical conditions. With each eye we see a separate object and, according to the law of corresponding points, it is necessary that the images of the object fall upon corresponding points of the two retinæ in order that single binocular vision may be realized. For central vision these points are the two maculæ, and for peripheral vision, these points must be equally to the right, to the left, above or below the two maculæ.



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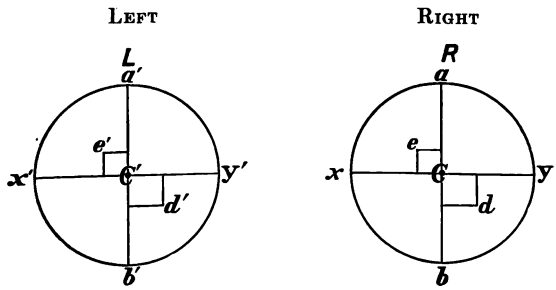

FIG. 1.— CORRESPONDING RETINAL POINTS. (LE CONTE.)

The field of binocular single vision is that portion of the two fields which can be seen by both eyes simultaneously, the projection of a single impression depending upon the semi-decussation of the fibers of the optic nerves, which occurs only in man and the higher apes. Semi-decussation is, therefore, the first physical essential.

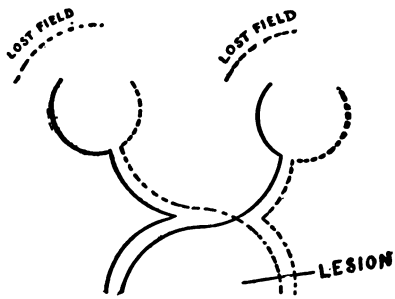

FIG. 2.— SEMI-DECUSSATION OF OPTIC NERVES.

To explain this, and the clinical facts of hemianopsia, it is assumed that at the chiasm each neuron divides into two, one of which crosses to the nasal side of the opposite eye, while the other goes to the temporal side of the eye on the same side, the end organs occupying corresponding points in the two retinæ.

A second physical requisite is the perfect

co-ordination of the twelve extrinsic muscles, that the eyes may be so directed to any point in the binocular field that the images shall fall on corresponding points.

When it is realized that a deviation of less than a millimeter* in the position of corresponding points means diplopia for small objects, it is almost inconceivable that any mechanics alone could secure the desired result.†

THE FUSION FACULTY.

According to Worth, sight in the newborn is limited to fixation of a light, so that all the finer qualities are the result of personal experience. The involuntary movements of the eyes of infants would show that there is no conception of binocular vision. The full development of the fusion faculty is not attained until the fifth or sixth year with the normal child.

Physiological diplopia means that objects

*According to Suter: "Refraction and Motility of the Eye," page 142. "The fovea centralis, upon which falls the image of every object attracting mental attention, does not exceed 0.4 mm. in diameter." Taking the distance of the nodal point in front of the retina to be 15 mm. Dennett, of New York, has shown by theorem of similar triangles, that, at a distance of one-half meter, an object to be discerned with normal acuity cannot exceed 13.5+mm. in diameter.

†Sanford: "Experimental Psychology," page 106.

nearer or farther than the point fixed are always seen double, but the adult has so far succeeded in ignoring this that it is sometimes difficult to make him realize the doubling.

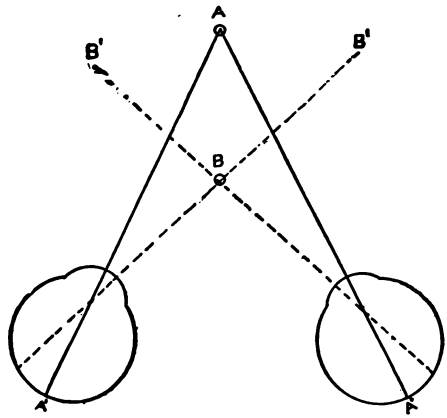

FIG. 3.— PHYSIOLOGICAL DIPLOPIA OF OBJECTS FARTHER OR NEARER THAN THE POINT FIXED.

There can be little doubt that this fact plays a very important rôle in the child's experience, the fusing at different distances developing the idea of perspective. Omiting the few cases of congenital defect, strabismus, better called heterotropia, if we adopt the more recent nomenclature, begins between the ages of one and four, a time during which the fusion faculty should be developing. The

significance of this fact in the treatment of this condition has been so ably presented by Worth that the reader is referred to his classic treatise, "Squint."

The argument is here introduced to emphasize the fact that the third essential to binocular single vision is the psychic one of the fusion faculty. Without such an overruling guidance, the necessarily exact coordination is inconceivable.

A discussion of the academic question of the existence of a fusion *center* is not essential to our purpose, and those interested are referred to Savage, "Ophthalmic Myology," and "Ophthalmo-neuro-myology"; Duane, "The Extra Ocular Muscles," in Posey & Spiller's "Eye and Nervous System."

The frequent clinical experience, that loss of sight of one eye is frequently followed by divergence, is an unanswerable argument for the importance of the fusion faculty in keeping eyes straight, and it is the purpose of this writing to show that it plays quite as important a part in the production and the cure of those *tendencies* to turn, grouped under the name heterophoria. Even Stevens, who did such pioneer work in calling attention to

heterophoria as a cause of asthenopia and reflex nervous disturbances, has devoted himself entirely to the physical side of the subject.

THE STEREOSCOPE.

The stereoscope is "an instrument for blending into one image two pictures of an object seen from slightly different points of view." This is exactly what binocular vision accomplishes. The distance between the eyes is the base line, and, therefore, each eye sees the object from "a slightly different point of view," and the extrinsic muscles and the fusion faculty are the "instrument" which does the "blending."

The only stereoscope in common use is the American, or Holmes model, which is exactly the same as the Brewster, except that it dispenses with the box and has an adjustable card carrier. The standard type consists of a pair of +5.25 lenses, so extremely decentered as to produce a prism of about 8^{Δ} base out before each eye. This deflects the rays from the corresponding points of the stereograph, so that a variable amount of convergence is needed to focus them on the maculæ.

If one is able to relax his convergence until there is a slight divergence, he can dispense

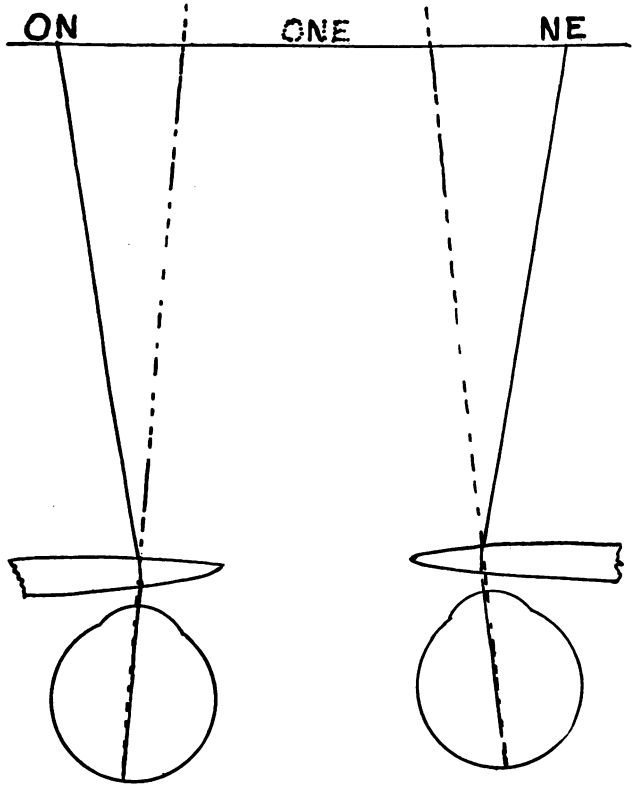

FIG. 4.— FORMATION OF IMAGE WITH HOLMES STEREOSCOPE.

with the stereoscope, but when looking at a near point we naturally converge. In the standard stereograph the distance between the

corresponding points varies, in the background it is 79 to 80 mm. while in the foreground it is 78 to 79mm. Thus, a relatively greater amount of convergence is required to fuse near points than far points, and this, together with the difference in angle of the two views, produces the appearance of relief. This is similar to what takes place in our perception of the outer world. The physiological diplopia, which exists for all objects, nearer or farther than the point fixed (see Fig. 3), is overcome by rapid fixing of the lines of sight on the nearer and farther points by more or less convergence.

It is recognized that this simple explanation of binocular vision is extremely incomplete. For a further discussion of the various problems involved, the reader is referred to the writings of Wheatstone, LeConte, Javal and Parinaud. Of the many other appliances for testing and training binocular vision, the most useful are Worth's Amblyoscope and the Bishop Harman apparatus.

CHAPTER II.

ORTHOPHORIA. — HETEROPHORIA. — STEVENS' PHOROMETER. — SAVAGE'S MONOCULAR PHOROMETER. — WELLS' HANDY PHOROMETER. — PRENTICE–WILLIAMS' PRISMOMETER. — SCREEN TEST. — DUCTION. — CAUSES OF HETEROPHORIA. — SYMPTOMS OF HETEROPHORIA.

ORTHOPHORIA — right tending — is the condition where both eyes *tend* to look at the same point at all distances. Those who believe in the disturbing influence of kataphoria and anaphoria would dissent from calling this a condition of perfect muscle balance. While orthophoria necessitates normal orbits, proper strength, insertion and nerve supply of muscles, it is also influenced by other factors. Sight requires accommodation for all distances, from ten inches to infinity, and fixation of the two eyes upon this spot. This is a most beautiful example of co-ordination, but is easily disturbed by an abnormality of accommodation, which may be in the ciliary muscle itself, or in a refractive error, which necessitates abnormal accommodation for its correction.

It therefore follows that muscle tests should be made with the patient wearing his correcting glasses, and also without, so that the *influence of the refractive error* may be determined. As absolute perfection is not to be expected, it would be advisable to adopt a *minimum* error which might still allow the classification orthophoria.

Heterophoria — cross or wrong tending — is the condition of most of the human family, if sufficiently careful tests are made. It would therefore be desirable to adopt some standard which recognizes a *minimum* of error to warrant the term heterophoria.

Only the principal forms, esophoria, tendency in; exophoria, tendency out; and hyperphoria, tendency of one above the other, will be here considered. Cyclophoria, a twisting tendency; anaphoria, a tendency of both eyes above the normal level; kataphoria a tendency of both eyes below the normal level, are conditions which the writer does not feel qualified to discuss, much less to treat stereoscopically.

METHODS OF TESTING.

Stevens' phorometer is probably most universally used. Savage objects to this method,

because both images are artificially displaced.

The Savage monocular phorometer consists of a rotary prism and a displacing prism *before the same eye.* This, he says, prevents the eye which is in the primary position from participating. This may be done with the phoro-optometer.

FIG. 5.— WELLS' HANDY PHOROMETER.

The same result is obtained with the Wells' handy phorometer, which consists of a single ten-diopter prism and a weighted disc.

When the prism is tilted until the double images are horizontal or vertical the index on the disc indicates the amount and kind of

heterophoria. This instrument is not intended to measure fractions of a prism diopter.

The Maddox rod is a very accurate test. A test which diagnoses and measures the error at the same time is one devised by Charles F. Prentice, of New York, in 1890.

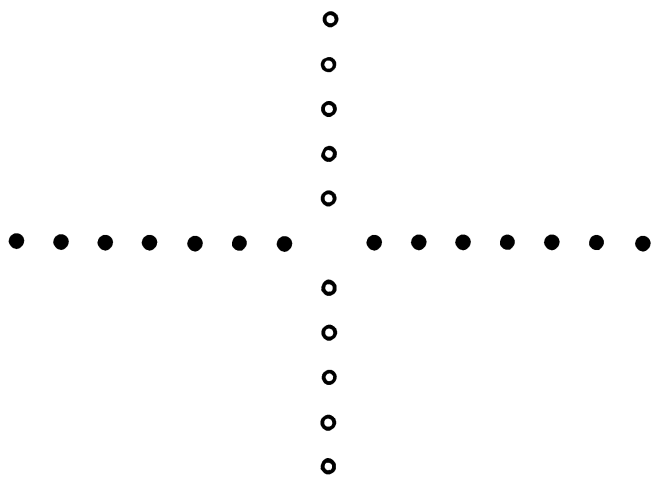

FIG. 6.— PRENTICE PRISMOMETER AND PHOROMETER.

It is based on the principle that a prism of 1^{Δ} causes a deviation of 1 cm. at 1 m., 5 cm. at 5 m., etc. It is, therefore constructed for any distance, 5 or 6 m.*

The Wells apparatus, which has been in

*Prentice: "Ophthalmic Lenses"— Shows that for exact tangent measurement of prism diopters, a 6 m. distance is essential.

use since 1891, is copied from Prentice, and consists of lights 1 cm. diameter, 5 cm. between centers, on the wall 5 m. from the patient.

Vertical lights are green — horizontal lights red. Patient is armed with red glass before one eye of sufficient color to obscure the green, green glass before the other eye of sufficient depth color to obscure the red. If red glass is before right and green before left, right eye will see horizontal red lights and left eye vertical green lights.

If orthophoria exists, a perfect cross will be seen as if both the colors were seen by one eye. If exophoria, green lights will be displaced to the right, *one spot for each prism diopter*. If only two red lights are seen to the right of the green, patient has 4^{Δ} of exophoria. Red line seen on a level with the first green spot below the center indicates 1^{Δ} right hyperphoria. Williams, of Boston, has improved this test by substituting luminous figures for the round spots, the arrangement being such that the tendency to "*horizontalize*" or "*verticalize*" is entirely eliminated. The theoretical superiority of this test is that it obviates the necessity of dis-

torting, blurring or displacing either retinal image.*

By all of these tests quite similar results should be obtained, but in one's record the particular tests employed should be indicated.

The cover or screen test is quite generally employed, and consists in alternately covering each eye with a card, while the patient fixes a distant light. The eye behind the card deviates if orthophoria does not exist, and recovers its fixation when the other eye is covered. Prisms held before one eye until all motion stops, measure the amount of the error.

This cover test differs from all of the others in that it is a strictly monocular test, and the influence of the fusion faculty is entirely eliminated. It is argued by the advocates of this method that it most truly reveals the real tendency.

In cases of high degree of heterophoria, or occasional heterotropia, the movement of each eye *behind* the screen should be observed —

*The writer has fallen into the habit of calling this the chromatic test. It might be called the "red and green," or perhaps the Prentice-Williams', unless someone has prior claim.

noting which recovers its fixation the more quickly on removing the screen. Obviously this is the favorite eye, and the one that lags will be the one that is suppressed in the tests of fusion to be given later.

DUCTION.

Whether the case be one of orthophoria or heterophoria it is important to know the strength of the recti muscles, as many orthophoric patients have such weak muscles that they are unable to do continuous near work without asthenopia or nervous disturbance.

Normal accommodation means that each eye shall be able to focus an object as near as 8 to 10 cm. If the pupillary distance be 60 mm., convergence to this distance requires 60^{Δ}. If the average reading distance be taken as 30 cm., 20^{Δ} would be used.

As the comfortable maintenance of accommodation at 30 cm. requires an *ability* to accommodate at 10 cm., so the convergence faculty must be much greater than the amount habitually used.

Cross* of Worcester, Mass., "believes that if the fusion range is not at least twenty

*Personal Communication.

per cent. in excess, there are apt to be more or less asthenopic symptoms."

Landolt* says, "We have tried to determine the quota of convergence, and our experience seems to demonstrate that this *reserve* amount ought to be about twice as great as the convergence required by the work."

Evidently the amount of reserve convergence necessary varies with the hours of application. It is certainly conservative to say that the actual power should be double that ordinarily used.

Duction is measured by the power to overcome prisms and maintain single vision. Loose prisms from the trial case may be used until the limit is reached, but the rotary prism is more convenient.

Howe† has maintained that the accurate measurement of duction requires the use of prisms in reverse direction, beginning with one *beyond* the patient's ability to overcome, and working down to weaker, until the strongest which can be fused is found. This method was adopted by the A. M. A., 1907, as the standard, which, it would be under-

*"Norris and Oliver System of Eye Diseases," Vol. IV, p. 133.

†"The Muscles of the Eye"

stood, had been employed when cases were reported to the society.

The writer pleads guilty to having continued the old way, but admits that repeated trials often give quite different results, showing increasing power.

Although there is no general agreement among the writers on this subject, it is probably conservative to consider 24$^{\Delta}$ as normal duction for the interni, 8$^{\Delta}$ for the externi.

CAUSES OF HETEROPHORIA

There are five generally accepted causes of heterophoria:

First. The malformation of cranium and orbits.

Second. Abnormal power, weakness or strength of one or more muscles.

Third. Tendons too long or too short.

Fourth. Insertions of tendons too far forward or back.

Fifth. Errors of refraction.

But it is the author's belief that a sixth cause, very generally overlooked, is an incomplete development of the fusion faculty. This does not mean that the patient possesses *no* fusion sense. Fusion faculty is a question

of degree. Many true strabismics have a rudimentary fusion power. The great majority of people can fuse large stereoscopic pictures, but many fail conspicuously when given type of the size ordinarily used. If only a slight suppression of one is detected during the test, we must remember that the very conditions of the test *force* the patient's *attention* to the separate objects for the two eyes, and that under ordinary conditions suppression is probably much more habitual.

It is also important to discover the *amplitude* of fusion. Many patients who possess a high degree of fusion faculty with the stereoscope adapted *exactly* to their normal balance, show but little power to overcome the slightest obstacle. Such cases cannot maintain correct fusion under the varying conditions which the ordinary use of the eyes imposes.

SYMPTOMS OF HETEROPHORIA

Errors of refraction and heterophoria are so often coexistent that it is difficult to assign to each factor its distinctive symptoms.

Not until the refraction has been determined under a cycloplegic can one be *certain* in

any given case that symptoms quite characteristic of heterophoria are not produced by the refractive error. Clinical experience in relieving a certain train of symptoms, which have persisted after correction of refraction, by treating the heterophoria, is the basis for the opinion here expressed.

In the order of importance the author would arrange the symptoms as follows.

Confusion.— No localized head pain, or pain may be referred to the suboccipital region or upper part of back. To the question, "In what part of the head is the disturbance?" the reply, "Oh, I don't know, all over," is so frequent that it is well nigh pathognomonic. Inability to fix one's mind on study or reading is a frequent complaint.

Difficult Fixation. — If esophoria, of a distant object, like a public speaker. If exophoria, annoyance in conversation in trying to "look one in the eye."

Vertigo. — Of mild type, probably better expressed by the word confusion.

Drowsiness — after reading but a short time.

General Nervous Disturbance. — This is a very large and somewhat dangerous subject,

but it is certainly conservative to say that heterophoria is frequently *a factor* in migraine, "nervous dyspepsia" and epilepsy. How small an error may give rise to symptoms is a matter of idiosyncrasy. The same may be said of refractive errors.

For a further discussion of this subject, the reader is referred to Stevens, "Functional Nervous Diseases" (1884); Howe, "The Muscles of the Eye" (1907).

CHAPTER III.

TREATMENT OF HETEROPHORIA. — PRISMATIC GLASSES. — OPERATIVE. — MUSCLE TRAINING. — STEREOSCOPIC TRAINING. — PHORO-OPTOMETER STEREOSCOPE.

TREATMENT OF HETEROPHORIA.

ORDINARILY the *time* for treatment is not until after the correction of the refractive error, as this alone may suffice to cure the heterophoria, and, as a general rule, with patients under thirty-five, not until the use of a cycloplegic has excluded latent refractive error. If the refractive error be slight, as compared with the heterophoria, one is justified in treating the heterophoria and ignoring the refractive error. If the treatment be by other means than the wearing of prisms, the patient is naturally quite pleased to be relieved without being condemned to wearing glasses.

METHODS OF TREATMENT.

First. — The wearing of prismatic glasses, simple or combined with the refractive correction, the prisms so placed as to correct all or part of the heterophoria. This is often

quite satisfactory in the low degrees, and may even reduce the error, but it usually has the opposite effect.

This increase is believed by many to be the simple uncovering of a latent tendency. In esophoria the liability to increase is greater, so that one may regret the procedure.

The use of prisms in the reverse position, to stimulate the defective muscle, has been advocated by some. The author's few attempts to follow this suggestion have not been sufficiently promising to warrant continuance.

Second. — Tenotomies and Advancements.

In the higher degrees (more than 10^{Δ} of exophoria or 5^{Δ} of esophoria) surgical interference is justified. For the indications the reader is referred to the advice of Jackson in "Wood's System of Ophthalmic Operations."

Although the writer has a number of successful tenotomies to his credit, the result in esophoria and exophoria has, on the whole, been unsatisfactory — usually insufficient. For extreme degrees of exophoria 20^{Δ}-25^{Δ}, advancement of the weak muscle gives good results. (The author is strongly in favor of advancement over tenotomy in all cases of

heterotropia.) *Certain it is that all surgery should be deferred until fusion and muscle training have been thoroly tried.*

Third. — Muscle Training.

This has been principally for exophoria. Gould arms the patient with a pair of prisms, bases out, 10$^{\Delta}$ stronger than he can fuse. Eyes are closed, and on opening he fixes a candle held 10 to 20 inches away. The accommodation assists the convergence and two lights are fused. Candle is carried to opposite side of room, while patient holds images fused. This process is repeated with increased strength of prisms until diplopia results.

Payne, of Boston, gives patients o. u. pr. 4$^{\Delta}$ to 8$^{\Delta}$ base out in a spectacle frame for home use. Candle is placed on opposite side of the room. This the patient fuses, counting ten slowly, the spectacle is raised and count is continued to twenty, still fixing the light. Prisms are lowered and count continued to thirty, raised and count to forty. This process is continued to one hundred and twenty, which should require about two minutes.

Loose Prisms.— It has been a very common

practice to supply the patient with half a dozen loose prisms from 3^{Δ} to 35^{Δ}, so that by combinations he can use an amount gradually increased 3^{Δ}. With these held before the eyes he fuses the two images of a candle across the room.

After noticing several patients allow an eye to deviate outward, suppress its image, and then declare they saw one, the writer decided that loose prisms could be used safely only *under the eyes of the oculist.* If there were any practicable way of utilizing binocular conceptions at a distance this objection might be overruled.

STEREOSCOPIC TRAINING.

The application of the stereoscope in the orthoptic treatment of strabismus — pre-and post-operative — is explained in Landolt's "Refraction and Accommodation of the Eye," 1886. He used the Brewster box stereoscope 166 mm. long with +6.00 lenses, the patient wearing his full correcting glasses, so that the pictures would be in focus without any effort of accommodation. His exercise object consisted of two cards, one sliding in front of the other, on one a vertical line above the hori-

zontal, on the other a vertical below, the position where the line became continuous showing the patient's fusion convergence. When this is found, the cards are adjusted towards the position for orthophoria and the patient strives to bring them together.

Later Richard Derby used a stereoscope mounted on a stand with object carriers which could be moved by an endless screw either vertically or horizontally. A modification of this is shown in Fig. 7.

In 1901 Worth brought out the amblyoscope, adjusting mirrors to Priestly Smith's tubes, so that fusion is possible notwithstanding a high degree of esotropia.

In all of these appliances the training is secured by moving *the objects*. The author's experience soon showed that patients would not follow well a moving object. The motion caused the fused image to break apart. This defect is probably less in the amblyoscope, as it is only the reflections of the objects which move. The fundamental principle of successful stereoscopic muscle training is the *insinuation* of the prismatic element by decentering strong spheres, *the objects remaining fixed.* This point cannot be over-emphasized

and will be referred to again and again. It is because of the smooth motion of the decentering screw for pupillary adjustment that the phoro-optometer is so well adapted for training.

In 1896 Javal published his great work "Manuel du Strabisme." He seems to have been the first to adapt the principle of the stereoscope to "latent strabismus," or heterophoria, and to him the writer feels most indebted. It was his stereoscope with five adjustments that suggested the utilizing of the phoro-optometer for the same purpose. It seems incredible that a work of such great merit should not have appeared in English.

His charts, graded from easy to difficult, opened up an entirely new and practical field in fusion training. In 1904 some of these were reproduced in English in the "Wells Selection of Stereoscopic Charts." Most of the other charts, like Kroll's, Dahlfeld's and Hale's, were adapted to secure only the rudiments of binocular vision.

Much good work can doubtless be done with an ordinary stereoscope, but in order to carry out the author's methods one must have a phoro-optometer, with two rotary

prisms and the stereoscopic attachment. The phoro-optometer had been in constant use several years before its adaptability as a training stereoscope was discovered.

The first apparatus was made with an adjustable focus so that spheres from +5.00 to +10.00 could be used. This was later discarded and a permanent distance of 10 cm. adopted. With this +10. spheres are always in focus.

Following the model of the late Dr. Richard Derby, adjustable object carriers were provided, with somewhat elaborate mechanism for vertical adjustment and an endless screw

FIG. 7.— PHORO-OPTOMETER STEREOSCOPE WITH ADJUSTABLE OBJECT CARRIERS

for approximating and separating them. This was essential to secure a gradual and smooth movement, otherwise the eyes ceased to follow and fuse the two objects.

After using this arrangement some time, it was discovered that patients who found great difficulty in keeping the objects fused as the carriers were approximated, were much less disturbed if the spheres were separated by turning the screw for pupillary adjustment, and that a much greater degree of prism could in this way be fused.

The 1902 model of the Wells stereoscopic attachment to the phoro-optometer, Fig. 7, shows the movable object carriers, but in the author's instrument they soon became fixed at 6 cm. apart.

It was later discovered that if one were a little careless in fixing the objects in the carriers, a slight tilting or vertical error interfered with fusing, so the object carriers fell into disuse and stereoscopic cards were used instead. The improved form is, therefore, simply the addition to the phoro-optometer of a clip to hold the cards. Fig. 8.

In 1904 the Wells selection of stereoscopic cards was published. This was a selection

of the most useful from those previously brought out by Kroll, Dahlfeld, Hale and Javal. Only a few new cards were added by the author.

FIG. 8.— NEW PHORO-OPTOMETER STEREOSCOPE SHOWING SIMPLE CLIP TO HOLD CARDS.

A second edition became necessary. The new edition includes some very ingenious tests in fusing complementary colors by Dr. George A. Shepard, of New York, and a

new set for amplitude training by the author. The lettering and grading have been somewhat changed.

To guard against any misunderstanding the *reader should bear in mind* that in the instructions which follow, the letters and figures refer to the second edition.

DECENTERING SPHERES TO SECURE PRISM.

The application of the principle of decentering of the spheres for the purpose of introducing extra prismatic effect, as applied to fusion training, is believed to be original with Javal,* but it has been greatly extended by the author, and its superiority over any other method known to him justifies a somewhat detailed description.

With o. u. +10., cards at 10 cm. are in focus. If the separation corresponds to that of the pupillary distance of the patient's eyes, no prismatic element is exhibited. If decentered 1 mm., 1^{Δ} approximately is produced. Thus +10. spheres make the calculation of the prism extremely simple. If the spheres are decentered out 5 mm., we have put before the patient 5^{Δ} of prism base

*Manuel du Strabisme," p. 115.

out, just as truly as tho a 5^{Δ} prism were inserted in the clip. If the spheres are decentered *in* 5 mm., 5^{Δ} base in is obtained. As the pupillary adjustment may be varied from 50 to 75 mm., it follows that 10^{Δ} or more may be utilized by this simple principle of decentration.

CHAPTER IV.

STEREOSCOPIC TREATMENT OF EXOPHORIA. — AUTHOR'S CARD FOR MEASUREMENT OF STEREOSCOPIC HETEROPHORIA. — AMPLITUDE OF FUSION. — RECOVERY EXERCISES. — HOME EXERCISES. — THE SUPPRESSED EYE. — CONTROLLED READING. — AUTHOR'S DEVICE. — NUMBER OF CASES TREATED AND RESULTS. — UNIFORM SCHEDULE FOR CASE REPORTS.

STEREOSCOPIC TREATMENT OF EXOPHORIA.

LET us suppose a case of exophoria of 10$^{\Delta}$ distance, adduction subnormal, greater convergence faculty needed. With o. u. +10. in the clips, centered to correspond to patient's pupillary distance, card marked B_1 is put in clip, and the patient is asked over which dot he sees the arrow. He will probably answer "five" or "between five and six." If five,

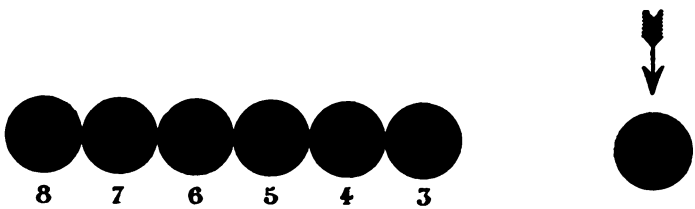

FIG. 9.— B_1. TO MEASURE FUSION CONVERGENCE.

this means that he has selected the number five spot, with which to fuse the arrow spot, therefore 5 cm. is the patient's easiest fusion distance with o. u. +10. Glasses correcting the refractive error should, of course, be worn and if there is much presbyopia, the o. u. +10. should be made enough stronger to correct it. This will slightly increase the prismatic effect of the decentering.

Eyes are closed and the two rotary prisms swung into position to give o. u. 5^{Δ} base out. Patient opens his eyes and again states position of arrow. If over six, the amount of prism which makes six centimeters the easiest fusion distance has been found. If not correct one or two trials will secure it. Should arrow be seen between six and seven, less than o. u. 5^{Δ} is required; should it be seen between five and six, more than o. u. 5^{Δ} is needed.

As all the cards, except series B, H and I, are 6 cm. between centers, the stereoscope is now approximately suited to this particular patient, and we, therefore, proceed to test his fusion faculty. Unless the case be one of anisometropia or amblyopia, it is well to begin with series F.

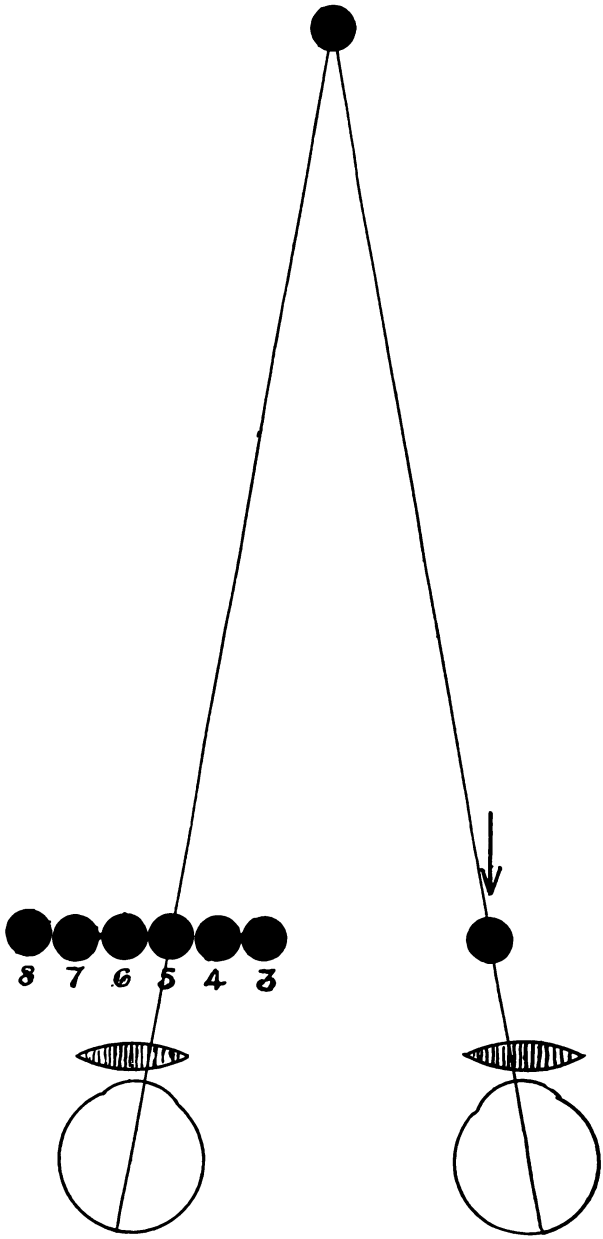

Fig. 10.—*Showing* the Lines of Sight when the Patient sees the Arrow over 5.

With F_1 patient should see the vertical line passing through the dot. If the line, which is seen by the left eye, is too far to the right, that is, heteronomous diplopia, the prism base out should be reduced until the direct alignment is secured. If the line be to the left of the dot, it is evident that the reverse is indicated.

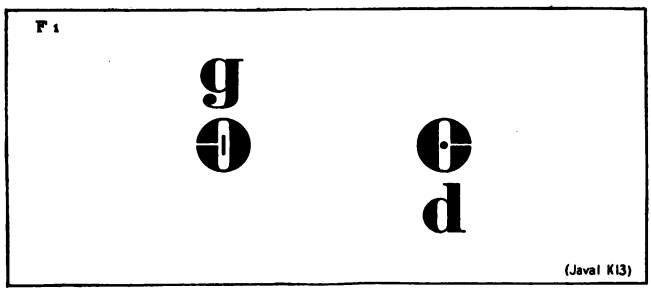

FIG. 11.— F_1.

By means of the card B_3 the exact prism needed may be determined. Obviously it is the amount with which the patient sees the lines intersect at six, but the cruder method with B_1 is preferable in the beginning.

B_3 is designed especially for the accurate measurement of *stereoscopic hyperphoria*, which is often quite different from that shown by other tests. The divisions of the red vertical line are 5mm. apart. If the black hori-

zontal line is seen to cross the red vertical line at H, 5$^{\Delta}$ right hyperphoria is exhibited. Hyperphoria may interfere with fusion. It is then necessary to correct all or part of it with a vertical prism in the clip.

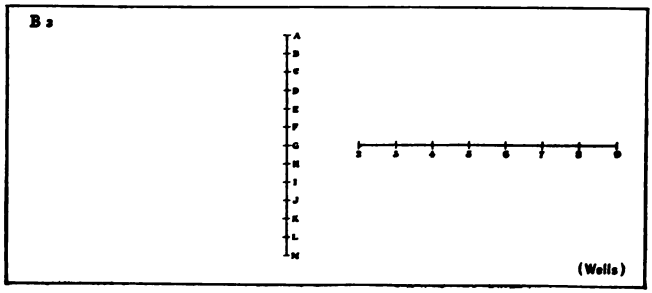

FIG. 12.— B_3. TO MEASURE STEREOSCOPIC HYPERPHORIA.

Patient's eyes are closed (unless otherwise stated, it is to be assumed that patient's eyes are always closed before each change) and succeeding numbers of F used in numerical order. It should be noted if either eye fails to see its respective lines and dots, and if suppression occur, whether it be always of the same eye or of alternate, right and left. Let us suppose that, beginning with F_4, the left eye fails to see the line or dots belonging to the left picture, although the letters are correctly read.

The case should be recorded:

"Stereoscope +10. = 5 cm., ⊂ Pr. o. u. 5△ B out = 6 cm. Suppresses Left $F_{4, 5, 6, 7, 8}$."

This test might have been made with C_9 or series G, but it has been found that series F furnishes quicker and more reliable information.

Series E is devoted to perspective.

If with E_1, the antero-posterior relation of the dots is correctly stated, the subsequent numbers are tried in order. If E_5 is not correctly seen, to the record is added "E, o. k. to 4" or "Fails E_5."

Much attention is given to series E, both in the office treatment and the home exercises (mentioned later) to develop fusion with perspective, and one should not be satisfied until the whole series can be easily perceived, not only when the stereoscope is adjusted for the easiest fusion distance, but also when the prisms are increased so that much convergence is required. E_4 is not well adapted for the purpose, because, with a single eye, the mathematical perspective is sufficient to suggest a cube. This card will be omitted in subsequent editions, and more cards added, which show no perspective unless really fused.

AMPLITUDE OF FUSION.

C_7 is now put in place, and as the N's are just six centimeters between centers, the two N's are perfectly fused and the patient reads "O N E."

Now while the patient watches the fused image, the P. D. of the spheres is increased by gradually turning the screw to the limit (75

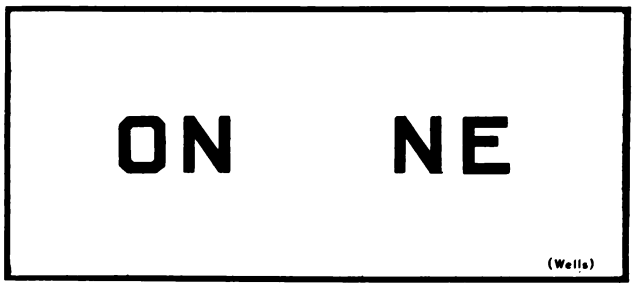

FIG. 13.— C_7. FOR CULTIVATING STEREOSCOPIC CONVERGENCE.

mm. P. D.). Eyes are then closed and P. D. of spheres is reduced to minimum (55 mm.). 5^{Δ} more, making 20^{Δ} in all, is now turned up in each prism. Patient will fuse this easily — but let us note just what has been accomplished.

Assume P. D. = 60 mm., then he has fused 20^{Δ} less 5^{Δ} = 15^{Δ}. As 10^{Δ} was required to bring the arrow over six on the B_1 card, 15^{Δ}

less $10^{\Delta} = 5^{\Delta}$ = effort put forth. This process is repeated, adding from 5^{Δ} to 10^{Δ} each time, until the "ONE" breaks apart before the spheres are fully separated. If this occurs, using o. u. Pr. 25^{Δ}, when spheres show 65 mm. P. D., record should read "amplitude 'ONE' or $C_7 = 55^{\Delta}$."

It is extremely important at the outset to let the patient understand that you are giving him your undivided attention, and that the same is demanded of him. It is better to allow no third person in the room, not even the assistant or secretary. The statement that this is really a test of one's will power, will put the patient on his mettle.

Much can be learned by watching the patient's eyes over the top of the phoro-optometer. Usually they both converge equally, but occasionally one eye will participate but little, and this will be the eye which is suppressed in the finer tests of fusion faculty. The treatment of this condition will be taken up later, but it is here noted to emphasize the importance of observing all the conditions.

In this particular, this form of stereoscope overcomes a serious objection to the amblyoscope, because with the latter the eyes cannot

be watched, and we must depend on the patient's statements, which are naturally very unreliable, especially when treating children.

But to return to our case:

The limit of fusion would be anywhere from 20$^{\Delta}$ to 50$^{\Delta}$ on this first trial. Phoroptometer is then removed and loose prisms held before the eyes base out, and strength increased until the limit for fusing a distant light is reached. The exercise should be stopped as soon as any fatigue is evident and pneumo massage, fine Faradic electricity or high frequency given. The pneumo massage is quite agreeable to the patient. For some years high frequency vacuum tubes have been used 50 milliamperes for five minutes. It may be that all this has no further importance than the soothing and suggestive effect.

This whole treatment requires 15 to 25 minutes, and is given three times a week for three weeks, or until sufficient power has been attained. Most patients gain rapidly, but some show little improvement after half a dozen visits. After the 60$^{\Delta}$ of the two rotary prisms has been fused, round prisms from trial case are inserted in the clips. It

is practicable to use as high as 10$^{\Delta}$ before the right eye and 20$^{\Delta}$ before the left. This furnishes 90$^{\Delta}$ in all without any decentering.

Just what constitutes sufficient power is not a fixed amount for all cases. Successful ones average 80$^{\Delta}$ to 90$^{\Delta}$ with the phoro-optometer stereoscope, and 50$^{\Delta}$ to 60$^{\Delta}$ loose prisms. Many, especially the younger, will

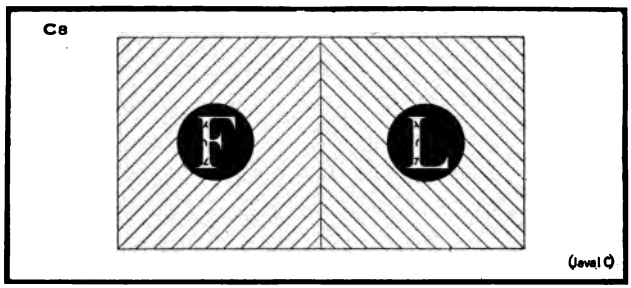

FIG. 14.— C_8.

develop an amplitude of over 100$^{\Delta}$, both with stereoscope and loose prisms. When sufficient power has been gained, time between treatments is gradually lengthened to two a week, one a week, one in two weeks, etc., provided the maximum reached at previous visit is still attainable.

It may be well to try the holding power of other cards, especially the L. F. the fusion

of which makes E, but it is believed that the ONE gives the greatest mental stimulus, as one's sense of proportion is disturbed at seeing the letters break apart.

RECOVERY EXERCISE.

The treatment is sometimes varied by what the writer calls the recovery exercise. With C_7 a few trials at decentering are made, the eyes allowed to close when the fusion limit is reached, and then the patient is told that this time his eyes are to remain open, that he must speak the instant he feels that he is about to lose his fused image, and that the prisms will be turned to help him get it clear again. It requires several trials before he can overcome the tendency to close the eyes, and then the prisms will need to be reduced very much before he will say "all right, I have it now."

After six or eight trials the recovery will be very much quicker and will require only a slight reduction of prism. It is believed that this exercise has considerable practical value in teaching the patient to overcome the slight turning tendencies, which may annoy him in reading.

HOME EXERCISES.

The patient is required to buy a Holmes' stereoscope with clips for inserting extra prisms, and a set of the Wells' stereoscopic charts. It is important that the patient own these, as he is expected to use them occasionally for some months, to insure his retaining his newly acquired faculty. These charts are not to be used indiscriminately, but in accordance with very exact instructions.

If at first examination the case showed a fair degree of fusion faculty, seeing half the cards in series F, G, and E, he is given F and G to use in numerical order, stopping when a few seconds fail to secure perfect fusion of the letters. This exercise requires ten to fifteen minutes and should be done three times a day.

After second visit, series E may be added to home work with instructions to run rapidly through F and G. When these cards, which are 6 cm. between centers, are mastered fairly (not necessarily perfectly), series H and I are to be used in the following manner: Patient inserts B_1, notes position of arrow and selects the same number of series H or I to begin with. For example, if with B_1 arrow is seen

over six, H_6 is the first to be used. This will be fused with ease, as it is the distance between centers to which patient and stereoscope are adjusted. The order is now toward the smaller number, $5\frac{1}{2}$, 5, $4\frac{1}{2}$, etc., as it is *convergence* amplitude which is needed. When

FIG. 15.— HOLMES' STEREOSCOPE WITH CLIPS FOR EXTRA PRISMS.

the narrowest of these cards can be easily fused, a pair of 5^{Δ} prisms is inserted in the clips, bases out, and the same exercise repeated. In many cases a pair of 10^{Δ} prisms is used.

This use of H and I must be explained to the patient with great care and he is given a card with the following printed instructions:

"Take card marked B_1. Notice the number of the disc over which the arrow is seen. Select same number of series H and I and work down to smaller numbers." On the same card the directions for all the home work are written; for example: "Series F, G, H and I, 10 to 15 minutes, three times a day."

In the average case ten to twelve treatments suffice to put the patient on an independent basis; that is, he has learned the knack, appreciates the relief of perfect fusion, and knows how to send the required neuricity to the internal recti.

For further refinement of fusion, Dr. George A. Shepard, of New York, has devised some very ingenious exercises in fusing colors. His instructions are as follows:

"Series D is designed to be used in those cases in which the muscular power is good, but the patient's ability to blend the images of the two eyes into a satisfactory binocular impression is deficient.

"As the fusion function consists of a subconscious control of the visual lines, it is essential that the activity of the psychic center be strongly stimulated. In order to do this,

cases must be individualized and such cards be presented as will best catch the attention and tickle the imagination. While it is still a moot point as to whether the perception of color is to be placed in the sphere of physiology or psychology, there can be no question that the blending of two monocular complementary colors into a neutral tint must be purely psychic. Where objects of the same form are to be fused, or where the separate images are incomplete, a desire for symmetry in the one and a striving to satisfy a memory picture in the other serve as strong incentives to fusion. Hence, it is necessary, in a certain proportion of cases, to eliminate these factors if perfect self-reliance is to be established.

"The D series has retained the same form and size of figure for the two eyes to aid the patient in properly adjusting the visual lines so the colored rectangles shall fall upon the corresponding retinal areas, but the neutralization of the colors demands that proper values be given to each impression. This series cannot be used to advantage if the patient has congenitally defective color sense or is suffering from nonconcentric contraction

of the color field, such as often occurs in neurasthenia.

"The exercise can be made still more exacting by having the form of the colors dissimilar and eliminating the control gray tint, but this would require the constant personal attention of the observer and make the charts less useful for home work."

FIG. 16.— SHOWING DOTS MARKED ON STEREOGRAPH.

Many years ago Landolt suggested the use of the ordinary stereoscopic pictures, putting two dots on one picture and a third dot on the other, so that the three will appear in a vertical line in the fused image.

For homework after the patient has ceased his regular visits, two or three dozen of such photos, selected by him, are marked in this

way, the dots being made as small as possible. He is thus taught to appreciate the absolute reproduction of natural scenery, and is constantly able to verify his binocular perception by a glance at the dots. These cards are used with the 5^{Δ} or 10^{Δ} prisms in the clips and thus combine fusion and convergence training.

It is advisable to insist upon good photographs properly mounted. The H. C. White Company of Bennington, Vt., offer a fine selection of views from all parts of the world.

Cross, of Worcester, Mass., has devised a cylinder with 14 facets, on which he has pasted the 13 cards of series H and B_1. This is mounted on the Holmes' stereoscope, arranged with a ratchet, so that the patient can turn up one after the other of the cards, progressing in either direction. Since it is wiser to have a period of relaxation between the repeated efforts of convergence, Cross suggests that patient's eyes should be closed while the cylinder is being revolved.

CONTROLLED READING.

Javal illustrates the control device of Bull, which is an affair somewhat resembling a

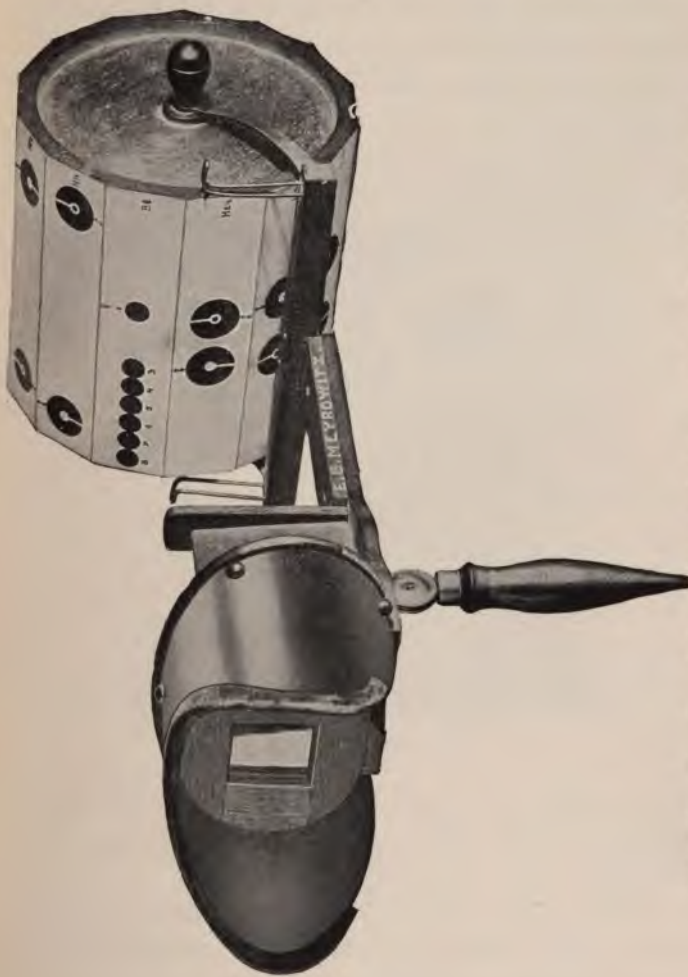

FIG. 17.— DR. CROSS' STEREOSCOPIC ATTACHMENT FOR HOME EXERCISING.

stereoscope with an opaque bar midway between the eyes and a card placed in the clips. To overcome the possibility of a patient reading alternately with right and left, Javal

FIG. 18.— AUTHOR'S CONTROL DEVICE.

constructed his "grill," a little table with five vertical bars. This is placed, standing on four legs, on the page to be read.

After experimenting with various appliances, the author devised a control which enables the principle to be applied to all of

the patient's reading, writing and sewing. It consists of an ordinary head band, either leather, silk or the metal spring, but in place of the mirror an aluminum band is attached by the ball and socket joint. This admits of considerable adjustment, which can be supplemented by bending the aluminum. The band is blackened to avoid reflections, and is placed half way between the face and the

FIG. 19.— TRIPLE CONTROL DEVICE.

page. If either eye be suppressed a black band is seen across the page. This is shown to the patient by alternately covering the eyes. If patient does not occupy a conspicuous place, this control can be used for practically all near work, and this is insisted upon. At first there will be some complaint, but most patients soon come to appreciate the steadying effect and the ability to read with more comfort.

The latest model, Fig. 19, has three control bands and resembles an inverted trident. The central band is 10 mm. wide, the lateral ones 7, and the spaces 13 mm. If this be held not more than 15 cm. in front of the eyes, the fields overlap sufficiently to allow of comfortable reading, but three times in each line the control principle is brought into play.

With a pupillary distance of 60 mm., the control at 15 cm. and the reading held at 35 cm. (14 inches), the overlapping is about 6mm. Obviously this increases with the distance.

This triple control necessitates more exact adjustment than the single band, and may not be practicable for *all* near uses, but for

quiet reading, it prevents suppression as effectually as Javal's "grill."

The author is familiar with Gould's theory of dextro and sinistro-ocularity,* but feels obliged to differ from the opinion that any marked suppression of either eye is physiological. Undoubtedly many people, who habitually suppress one eye, may not suffer any annoyance from this condition. The same may be said of errors of refraction, but does any one for that reason consider astigmia physiological? The writer maintains that the habitual use of the two eyes binocularly, with a minimum of suppression of either, is as ideal as is the emmetropic eye to uniocular-vision.

Therefore, every known means is utilized to overcome this suppression. If marked, it is admissible to atropinize the favorite eye. One of the less powerful cycloplegics is generally sufficient. A thin film of soap may be smeared on the stereoscopic lens, corresponding to the *favorite eye*. The whole object is to force the patient's use of the suppressed eye, by handicapping the favorite one.

Ophthalmology, Oct., 1904.

NUMBER OF CASES TREATED AND RESULTS.

In advocating a new method of treatment, it is realized that something must be said about results, but it is a somewhat difficult task to report accurately concerning therapeutic accomplishments.

Probably nine-tenths of those treated have been exophorics, so that of this class there have been a sufficient number to justify one in drawing some conclusions. In the last five years 330 cases of this class have been treated by the methods explained above. Of these about sixty per cent. have gained a good convergence faculty varying from 60^{Δ} to 90^{Δ}, and the symptoms have been relieved. Some of these have become orthophoric by the various phorometer tests. Others still exhibit some exophoria, but much less than before. These are all classed as "cured." Fifteen per cent. have developed equally good convergence, but symptoms are not relieved. Evidently symptoms were not caused by insufficiency. Fifteen per cent. more have attained to 30^{Δ} or 40^{Δ} and secured partial relief.

About ten per cent. must be classed as failures. No improvement in muscle power

could be secured. For some reason they did not respond. These last were not given a full course of treatment. If marked improvement is not evident after five or six visits, the treatment is stopped.

Undoubtedly this list includes some cases of nervous instability, which a keener diagnostician would have referred to the neurologist. There have been some relapses, but the great majority of the "cured" cases have retained sufficient power for all practical purposes. Patients are admonished to test themselves, from time to time, with the stereoscope and cards, and if they notice any loss of power, to renew the home exercises.

UNIFORM SCHEDULE FOR CASE REPORTS.

Since the above was written five years ago, over three hundred more of this class have been treated. Last year the writer presented a paper* entitled "Uniform Schedules for Case Reports Necessary for determining the Value of Different Forms of Treatment. The Practical value of the one presented tested by the report of two hundred and thirty-six cases of Exophoria and Convergence In-

*Journal Ophthal. Otology & Laryngology, Dec., 1917.

CASE NO.	SYMPTOMS H Headache P Pain in Eyes V Vertigo C Confusion	EXOPHORIA				DUCTION				Fusion Faculty	No. Treats.
		Phorom.		Cover.		Revolving Pr.		Loose Pr.	Stereo.		
		D	N	D	N	Ad.	Ab.	Ad.	"ONE"		

FIG. 20—SCHEDULE FOR REPORTING HETEROPHORIA CASES.

sufficiency Treated by Stereoscopic Fusion Training."

The careful tabulation on such a schedule requires considerable time, but if generally adopted would enable one to judge of the relative merits of different methods of treatment.

The figures are as follows:

155 cases of Exophoria at distance treated
70 " " or 41% symptoms cured
82 " " " 34% " relieved but not cured
14 " " " 8% " not relieved
19 " " Result not stated or treatment stopped, record incomplete. Assuming that these were not relieved, would make the number of failures 33, or 21%

81 cases of Insufficiency Convergence treated
36 " " " or 44% symptoms cured
34 " " " " 42% " relieved
7 " " " " 8% " not "
4 " " " Result not stated or treatment stopped, record incomplete. Assuming that these were not relieved, would make 11 failures, or 15%

SYMPTOMS C=Cured >=relieved not >	PHORIA				DUCTION				% Loss after 6 mos.	REMARKS
	Phorom.		Cover.		Revolving Pr.		Loose Pr.	Stereo.		
	D	N	D	N	Ad.	Ab.	Ad.	"ONE"		

While these figures may not be quite as good as the more general statement of five years ago, they are painstakingly exact, and it is every day evident that the results are increasingly satisfactory.

CHAPTER V.

STEREOSCOPIC TREATMENT OF ESOPHORIA.— MAY BE AN EXPRESSION OF CONVERGENCE INSUFFICIENCY.— FUSION TRAINING SAME AS FOR EXOPHORIA.— AMPLITUDE TRAINING THE REVERSE OR MAY BE THE SAME AS FOR EXOPHORIA.

ESOPHORIA.

THE proper treatment of esophoria necessitates a careful estimation of all the factors concerned. One is not justified in concluding that the convergence faculty is too strong. Esophoria at distance is often associated with exophoria at near. In these cases duction will be found quite limited.

Paradoxical as it may seem, the writer is convinced that esophoria at a distance is not infrequently an expression of convergence *in*sufficiency. Just how this is brought about he has no very definite opinion, but as the convergence function is the one most directly under the control of the will, it is conceivable that it might be exercised "not wisely, but too well," in a vain effort to overcome some annoying exophoria or hyperphoria.

Esophoria, dependent upon latent hyperopia, is quite common, and there is a consensus of opinion as to what this association implies. The constant need of innervation of the ciliary for distance, as well as near, in some way causes an overstimulus of the associated convergence — the coordination is disturbed. The full correction of the whole refractive error under atropine is, therefore, the first requirement and usually gives relief, but many of these cases show no reduction of the esophoria, the symptoms persist and the blurring of distant objects is quite annoying. For these cases and those not hyperopic, what shall be done? The use of prisms base out frequently "begets the calamitous necessity of keeping on." With each increase of prism more esophoria develops, until one may be forced to do a tenotomy or advancement to give his patient relief.

The stereoscopic treatment consists first of a thoro testing of the fusion faculty, and if any defect be found, the use of controlled reading (explained in Chapter IV) and the stereoscopic charts which cultivate a refinement of fusion, like F, G, D, E. To

this point the treatment may be identical with that given for exophoria.

In using the phoro-optometer stereoscope, patient should learn to fuse with prism base *in*, if we are to secure a greater divergence power. The same o. u. +10. are used in the frame, and card B_1 determines the easiest fusion distance by position of arrow. Let us suppose it to be seen over three, this means that the two discs 3 cm. apart are the easiest fusion distance.

Rotary prisms 15^{Δ} each base out ought theoretically to bring the arrow over 6. C_7 ON NE is then introduced and the spheres approximated so as to *reduce* the base out of the rotary prisms. When limit has been reached, patient's eyes are closed and the lenses separated as far as possible, and the base out of the rotaries reduced 5^{Δ}, leaving 10^{Δ} each.

If the patient's pupillary distance be 60 mm. and the phoro-optometer show 70 mm. P. D., 15^{Δ} each base out will be exhibited in this wide position and this will be as easily fused as at first. Now if the spheres be *approximated* while the patient holds the letters fused, when P. D. 60 has been reached, the prismatic element of the decentering has

been eliminated, and the amount as shown by the revolving prisms, 10$^{\Delta}$ each, is the total. If the approximation be continued to 50 P. D., then the 5$^{\Delta}$ each base *in* produced by the decentering reduces the base *out* of the revolving prisms, and the patient has diverged from his first position and maintained fusion with o. u. 5$^{\Delta}$ base out.

Eyes are now closed again and the spheres separated as far as possible. Rotary prisms are now *reduced* 5$^{\Delta}$ each, so that the reading which was before 10$^{\Delta}$ is now 5$^{\Delta}$. Patient opens his eyes and if he is able to fuse the ON NE, lenses are approximated as before. This process is repeated with smaller changes in amount of rotary prisms as it becomes evident that patient's limit is being reached.

As was said before, the home use of the cards as far as series G is the same with all forms of heterophoria, because with all of these cards the distance between centers is 6 cm., and their use is for the cultivation of a refinement of the fusion faculty. For amplitude training it is evident that the progression in the use of series H and series I must be reverse of that for exophoria; that is, if patient sees the arrow over 4 with B_1 card

he should commence with H_4 or I_4 and work *up* to *higher* numbers, 5, 6, 7, etc.

In many cases where there has been present esophoria for distance and exophoria for near the convergence duction has been found so poorly developed that the writer has treated the case the same as for exophoria, both with the phoro-optometer stereoscope and the homework for cultivating amplitude.

Increased convergence has relieved the symptoms and *has not increased the esophoria.* In some instances orthophoria has been restored. It is experiences like these which have forced the conclusion that there exists a pseudo-esophoria, which should be interpreted as an *insufficiency* of convergence and not excess.

CHAPTER VI.

TREATMENT OF HYPERPHORIA.— STEREOSCOPIC TREATMENT NOT PRACTICABLE.— PRISM DUCTION TREATMENT.— AUTHOR'S CARDS FOR RIGHT AND LEFT HYPERPHORIA.

HYPERPHORIA.

In a few cases stereoscopic treatment has been attempted with revolving prisms. The hyperphoria, as indicated by cards B_2 and B_3, is corrected by revolving prism. The ON NE card is introduced, and while the patient holds the image fused the prism correcting hyperphoria is reduced to zero, and as much reverse prism used as the patient will endure without losing the fused image. This is a kind of stereoscopic duction and can be repeated as many times as thought desirable. The results have not been sufficiently good to warrant its continuance.

In 1908 the writer devised two new series which were published as a supplement to the first edition of stereoscopic charts. These were designed for the treatment of hyperphoria. The characters ON NE were made of block letters 8 mm. square, horizontal

separation being 60 mm. in all. Each set consists of five cards. For right hyperphoria the right object NE is lowered 2, 4, 6, 8, 10 mm., corresponding to right hyperphoria of 2^{Δ}, 4^{Δ}, 6^{Δ}, 8^{Δ}, 10^{Δ}, if measured at 10 cm.

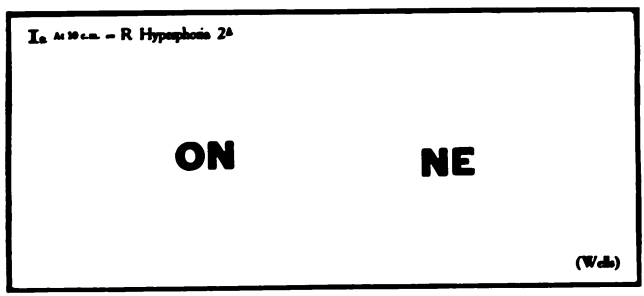

FIG. 21.— DISCONTINUED SERIES.

For left hyperphoria the left object ON is lowered 2, 4, 6, 8, 10 mm., corresponding to left hyperphoria of 2^{Δ}, 4^{Δ}, 6^{Δ}, 8^{Δ}, 10^{Δ}, if measured at 10 cm.

The writer's idea was that if a patient with right hyperphoria of 8^{Δ} could fuse 1_8 most easily, he should be able to progress to 1_6, 1_4, 1_2, and thence to the ordinary cards with both sides horizontal. The results, however, were not satisfactory even when hyperphoria measured with B_4 in stereoscope at 10 cm. corresponded to hyperphoria measured

at 5 M. Since no one with whom the writer has communicated has had better results with series I and J, they have been omitted from the second edition.

A stereoscope might be constructed in which the spheres could be decentered vertically and the same principle applied as for

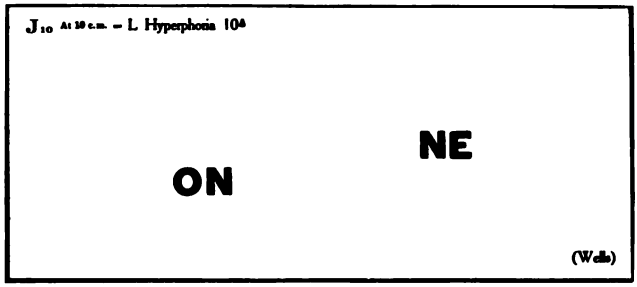

FIG. 22.— DISCONTINUED SERIES.

training convergence and divergence, but of the result the writer is not particularly sanguine.

Hyperphoria frequently disappears as the convergence power increases, and if it remains in sufficient amount to give rise to symptoms, it is the author's practice to correct it with a prism, or if of high degree by tenotomy or advancement.

CHAPTER VII.

STEREOSCOPIC TREATMENT OF HETEROTROPIA. — OF CONCOMITANT ESOTROPIA.— THE AMBLYOSCOPE.— AUTHOR'S DEVIOMETER. — THE PERCENTAGE OF CURES.— TREATMENT OF ALTERNATING ESOTROPIA.— TREATMENT OF EXOTROPIA.— THE TIME FOR OPERATION.

ESOTROPIA.

Ever since Worth's first publication in the *Lancet*, May 11, 1901, the writer has been a conscientious follower of his methods. His suggestion of atropinizing or bandaging the fixing eye for months is certainly of great value, and although it had been previously practiced by Landolt and Javal, Worth did well in emphasizing it so forcibly.

A certain number of cases of concomitant esotropia can be cured by this method and the use of the amblyoscope, but this latter instrument has been rather disappointing. There are definite drawbacks to its practicability. In the first place, one cannot see the child's eyes and is, therefore, forced to depend on his statement as to what he sees.

The imagination of the child is very vivid and no one who has tried to carry out this treatment can have failed to be at his "wit's end" many times to know just what was

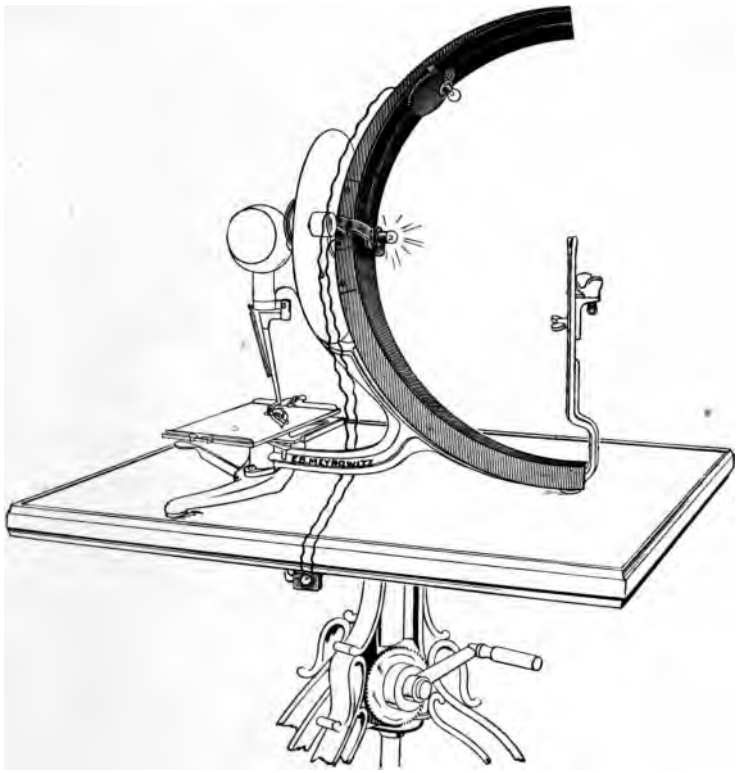

FIG. 23.— THE AUTHOR'S DEVIOMETER ATTACHMENT TO THE PERIMETER.

taking place. Then it is absolutely essential that the case be seen early and that the parents' intelligent co-operation be secured.

Following Worth's suggestion the writer devised a deviometer attachment to the perimeter, with which it is possible to measure the angle of the deviation in quite young children.

A concealed switch is so arranged that the central light, which the child naturally fixes, is put out at the same instant the movable one is lighted. Thus, before he has time to change his fixation, the reflection of the movable one is noted on the cornea. A few trials suffice to make it central, and the degree of heterotropia is read off on the arc.

This ability to make comparative measurements is an essential part of the treatment, in order to know if the error is getting less. The wearing of full correcting glass in the fixing eye, and occasional atropine in the same, with some less than full correction of refraction for suppressed eye, will usually reduce the error one half. Little more than this can be done with a very young child. As soon as possible Worth's marble test should be used to get a crude idea of visual acuity.

When the child is able to comprehend the

Worth amblyoscope, it is given with the simplest pictures for home use, and the phoro-optometer stereoscope used at the office. Fusion can often be secured with the latter in a case needing o. u. prism 30$^{\Delta}$ base out. Here we make use of A_1 for left esotropia—A_2 for right esotropia.

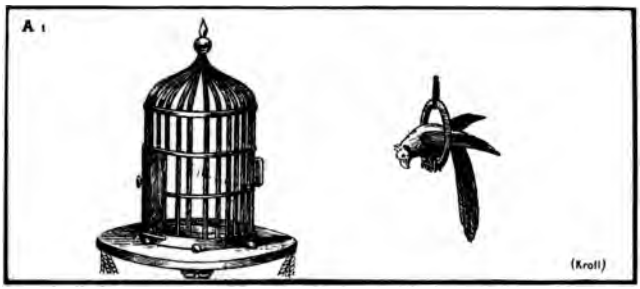

FIG. 24.— A_1. FOR LEFT ESOTROPIA.

Not until concrete pictures like C_1, C_2, C_3 can be fused need one expect much from stereoscopic exercises.

There is very little holding power in discrete pictures, either with the stereoscope or amblyoscope, — the bird *out of* the cage makes just as pleasing a picture as the bird *in* the cage, but when the head of C_2 loses an eye or an ear, one's sense of propriety is offended.

The prismatic element can be reduced by

decentering, the same as in treating esophoria, and the eyes may be watched all the time over the top of the instrument to note their movements. In a favorable case the home stereoscope with as high as o. u. 15$^{\Delta}$ base out can be used, the amount being reduced as conditions warrant.

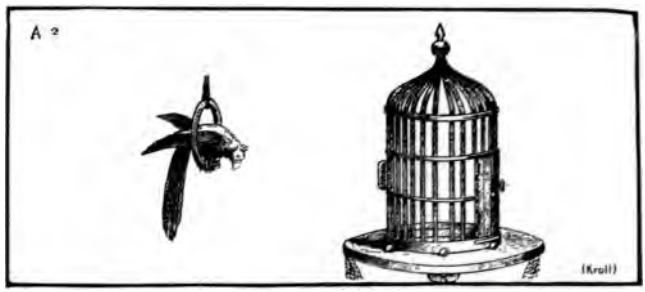

FIG 25.— A_2. FOR RIGHT ESOTROPIA.

It is somewhat difficult to state exactly the percentage of cures that may be expected by orthoptic treatment alone. It is almost impossible to carry out the full treatment with dispensary patients.

Of all the private cases of esotropia seen by the writer during the last five years, only twenty-five per cent. were less than six years old. Some of these moved away and were referred to colleagues in other cities. Others gave up the treatment after a few visits.

Excluding the congenital cases, nine per cent. were given the recognized orthoptic treatment, and of these nearly three-quarters were cured and developed a fair degree of binocular vision. A few cases, averaging thirteen years of age, responded to glasses and fusion-training methods. Most of the other cases were corrected by advancement of one or both externi. Post-operative fusion training has been used in all except those lacking all fusion sense.

Since only twenty-five per cent. were less than six years old, it is evident that it is still necessary to emphasize the importance of beginning this treatment early.

The intelligent co-operation of the family physician means that he shall refer every case to his ophthalmic surgeon, whenever there is discovered even an *occasional* squint. It is true that the wearing of glasses under two years is attended with some difficulty, but many other expedients can be used to force the seeing with the turned eye. These may be atropine in the fixing eye and an occlusion bandage. The object of this very early treatment is to preserve the turned eye from amblyopia exanopsia, and to cultivate

the fusion faculty during those years when it is developing in the normal child.

This treatment should be continued as long as the deviometer shows improvement. This may be months or years, but it is certainly a mistake to delay operation too long. A rudiment of fusion can often be trained into a refined faculty if the eyes are put approximately straight by operation. This may be as early as five or six years of age, provided the operation be an advancement without a tenotomy.

ALTERNATING ESOTROPIA.

In these cases vision is usually equal in the two eyes, and there is very little refractive error. A cycloplegic, or even a slight blurring of either eye, causes it to converge and the other eye to fix. Fusion faculty is usually nil, and any sort of orthoptic treatment generally of little use. Advancement of both external recti is usually required.

EXOTROPIA.

If occasional, stereoscopic treatment and fusion training will usually cure the exotropia, the method is the same as for exophoria.

The result is often orthophoria by phorometer, Maddox rod or chromatic test, but exophoria may be still shown by the screen test. As the normal condition of the individual is with both eyes participating, it seems appropriate to use a binocular test, especially the chromatic, in which the tendency to horizontalize and verticalize is reduced to a minimum. This also shows the value of the fusion faculty in maintaining orthophoria. If the exotropia exists all the time immediate advancement of the internal rectus, *followed* by stereoscopic training, is indicated.

CHAPTER VIII.

MUSCULO-CAPSULAR ADVANCEMENT. — AUTHOR'S MODIFICATION OF WORTH TECHNIC. — THE SCLERAL ANCHOR. — AUTHOR'S FIXATION FORK. — SCHEDULE FOR CASE REPORTS.

MUSCULO-CAPSULAR ADVANCEMENT.

DEFINITION. — "American Encyclopedia of Ophthalmology, Advancement," by Edward Jackson: — "An operation whereby the tendon of the ocular muscle is separated from its insertion, and attached at a point farther removed from its original attachment. In this way the muscle acquires increased power over the excursions of the eye. There are numerous operating methods, but in all cases the tendon of the impaired muscle is loosened and, by means of sutures, is drawn forward to a point in advance of its original insertion. Section of the opposing muscle may precede or follow the operation. Advancement operations differ from each other as to whether the muscle is advanced upon the eyeball along with the other tissues with which it is related (musculo-capsular advancement), or

whether the attempt is made to partly separate the muscle from the related structures and bring it forward alone."

Landolt's article in Norris & Oliver's System (1900) was the first thoro discussion of this subject which came to our notice, and in 1901 the author had the pleasure of seeing his technic. At this same visit he one day remarked: "My next case is a very unusual one, requiring an operation which I rarely perform." After thus exciting the curiosity of his observers he proceeded to do a simple tenotomy of an internal rectus, first showing that, notwithstanding both externi had been previously advanced, a small amount of esotropia persisted. It would appear that Landolt was the first to urge advancement for all forms of strabismus, postponing tenotomy until double advancement had proved insufficient. Since 1878 he has insisted upon the superiority of advancement over tenotomy, disproving the assumption that the opposite muscle gains what the tenotomized loses. By many his views were thought extreme and many of the world's greatest ophthalmic surgeons have continued to perform tenotomy as the first operation.

In the summer of 1901 the author saw Worth demonstrate his operation before the surgeons at the Royal Ophthalmic, and after reading his reasons in "Squint" he decided to adopt it. The first attempts were so satisfactory that he has continued to employ his technic, with slight modification, to be mentioned later. A careful re-reading of Landolt raises the question of just what Worth's contribution was. Both are the musculo-capsular variety. Worth's advocacy of the twisted waxed suture, and the method of securing the cut end, are extremely important. There is *no* cutting out of the tendon suture, and the blood supply of the muscle is not interfered with. This essential feature of the Worth operation has been generally overlooked, and many of the illustrations of the same show the *single* thread. Worth keeps a supply of suture material all prepared. It has been found easier to prepare it fresh for each operation. Black silk No. 8 is threaded through a *new* No. 24B half curved needle, the point of which has been tested on the drum. It is then twisted, doubled, and a knot tied in the end. It is then run through the fingers from the needle end to

rub out any kinks. Three such sutures are prepared for each case, in order to be ready should one suture be cut in excising the tendon and conjunctiva behind the advancement forcep. (This accident has occurred once.) These are wound around a piece of gauze and boiled with the other instruments. As soon as they come out of the sterilizer they are wiped with sterile gauze and dropped into a jar of melted white wax and vaseline. After a few minutes they are fished out with a strabismus hook, again wiped with gauze to get rid of the surplus wax. A smooth, pliable double suture is thus obtained, which slips through the tissue easily, and has much less tendency to cut out than a single thread.

Worth's Technic.—Vertical Incision 10 to 12 mm. long, 1 mm. from corneal margin. Dissect from sclera all tissue well above and below tendon, but avoid interference with central portion. Secure plenty of clear space so that large strabismus hook may be introduced well behind attachment, far enough above and brought out far enough below to include all tendon fibres. Advancement forceps is then substituted, — not clamped until it is seen to be perfectly vertical, with both

eyes open. Tendon is excised close to sclera. Sutures, Worth method, introduced *thru muscle, capsule and conjunctiva* and tied, the distance behind the forceps varying somewhat with the error to be overcome, but usually as far back as convenient. We have no fear of over-correction. Landolt says, "One must get a very strong divergence in convergent

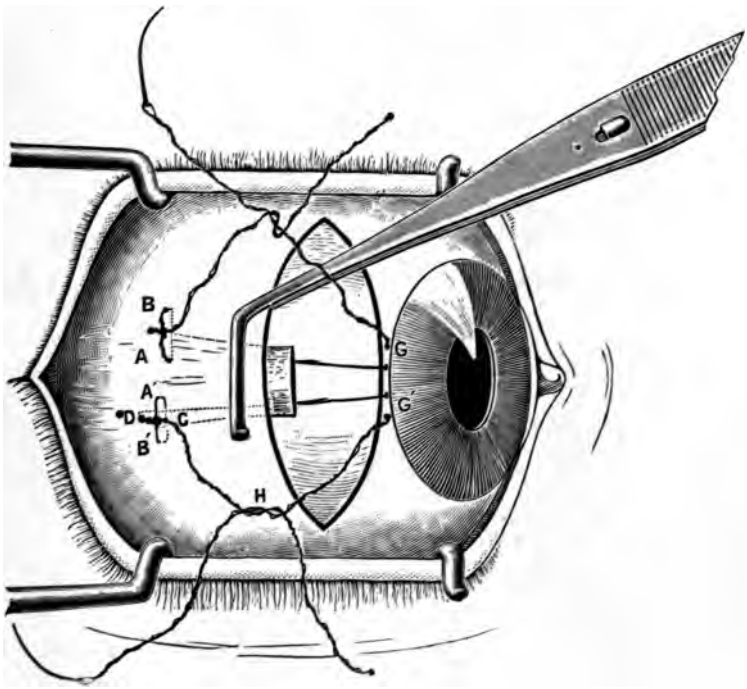

FIG. 26.— AUTHOR'S MODIFICATION OF WORTH ADVANCEMENT.

strabismus." All the tissue, conjunctiva, tendon and capsule is now excised 1 or 2 mm. behind advancement forceps. This is done before inserting needles in sclera, to avoid cutting sutures. Worth's technic is followed exactly until we come to the scleral anchor.

The Scleral Anchor. — This is really the only difficult part, but upon it depends the success of the operation. Our method of introducing the scleral stitch is more like Landolt's and Meller's than Worth's. Instead of introducing needles horizontally, they are inserted deep into scleral tissue at right angles to line of tendon, 1 mm. above and below middle line, and brought out 3mm. above and below. This differs slightly from the Meller and Landolt method, in that they carry the needles obliquely up and down for a few more millimeters thru loose conjunctiva. This seems to us wrong in principle, for after securing a firm hold in the scleral tissue, the inclusion of more conjunctiva and necessarily the use of more thread tends to make less secure the scleral anchor. By the Worth method we found that the fear of entering the anterior chamber was apt to prevent getting deep enough hold.

THE FIXATION FORK

It is difficult to get a sufficiently strong hold for the counter pressure. If the cut surface of the conjunctiva is grasped with fixation forceps, it is liable to tear away. Worth grasps the stump of the cut tendon. This is all right if one introduces the suture horizontally, but it is not opposite the point of insertion of the needle when introduced at right angles to the tendon. To overcome this trouble the author has devised a fixation fork which has two sharp points 1½ mm. apart, the web being reduced to a knife edge.

FIG. 27.— AUTHOR'S FIXATION FORK.

This is applied to the conjunctiva directly opposite the point of insertion of the needle and 2 or 3 mm. beyond the place where the needle is to emerge. The conjunctiva slips a little as the points penetrate it and get their hold in the sclera itself. The eye is now held firmly between the needle and the fork,—can be moved in any direction and even lifted. The needle is now pushed home, the attempt being to reach two-thirds of the

thickness of the sclera, the point emerging between the tines of the fork.

The distance from entrance to exit of needle is 2½ to 3 mm. From experiments made on eyes about to be enucleated we have no doubt that the sclera is frequently penetrated, but have never seen any harm from this. In fact, in over one hundred operations by the

FIG. 28.— WELLS' MODIFICATION OF WORTH'S ADVANCEMENT. HORIZONTAL ANTERO-POSTERIOR SECTION. THIS DOUBLE AND TWISTED SILK SUTURE WAS INSERTED IN AN EYE ABOUT TO BE ENUCLEATED IN A DIRECTION AT RIGHT ANGLES TO THE LONG DIAMETER OF THE MUSCLE, AND SHOWS THE DEPTH OF BITE ESSENTIAL TO PREVENT CUTTING OUT.

author and his colleagues at the Massachusetts Homœopathic Hospital, there has been absolutely first intention healing. Before tieing the sutures the antagonist is given a thoro stretching with a small tenotomy

hook. The first half of a surgeon's knot is made in each suture and the two are tightened simultaneously by the operator and his assistant. When the structures are brought close to the cornea, one knot is finished, while constant traction is maintained on the other suture. Just how tight to tie is a matter of judgment. It can be overdone and cause cutting out. There should be considerable bunching of the conjunctiva at the corneal margin; that is, the tissues should be *advanced ad maximum*.

Local anæsthesia suffices for a child of over twelve years, unless he be especially nervous. After instillation of cocain, one or two drops are injected over muscle. Both

No. P=Private H=Hospital	Eye	Deviation Perimeter	c = constant oc = occasional alt = alternate	Age	Onset	Refraction = Cycloplegic	V	Glasses Ordered	Time Worn	Deviation = Glasses on
P 5300	L	20°	c	22	3	R+3.75=+1.00c 100° L+4.50=+1.50c 75°	.7 .6	R+3.00=+1.00c 100° L+3.75=+1.50c 75°	3 mos.	16°
P 6268	L	20° hyper 30°	alt	18	baby	R+2.00=+ .62c 65° L+2.50=+3.00c 95°	.7 .3	R+1.50=+.62c 65° L+1.50=+3.00c 95°	3 wks.	20°
P 6751	L	sclera cover'd	c	29	12 yrs.	R—.25c 105° L—1.75=—.50c 15°	1. .7	R—25c 105° L—1.75=—50c 15°	3 wks.	
P 7008	R	30°	alt	18	5	R+4.0c=+50c 75° L+4.00=+75c 115°	.6 .7	R+3.50=+50c 75° L+3.50=+.50c 75°	1 mo.	15°
		°			3	R+		R+1.00=+75c		15°

FIG. 29.—SCHEDULE FOR ADVANCEMENT CASES. ESOTROPIA

eyes are bandaged and the patient is kept in bed. Unless there should be pain and fever (which have never occurred), the dressing is not touched until the evening of the sixth day. Thereafter the unoperated eye is left open and atropine instilled. Sutures are removed on seventh day. Full correcting lenses are immediately put on and atropine put in operated eye, which is covered with light dressing for one day. The prominence of the advanced structures disappears in a few weeks, but the increased vascularity will be evident for some months.

In 1914* Drs. Wells and Sternberg reported the results of sixty-nine cases operated by this method on a comprehensive schedule,

*Journal of Ophthalmology, Otology & Laryngology, Sept., 1914.

Fusion Training	Previous Operations	Advancement	Antagonist Muscle	Anæsthetic	Results			Remarks
					Perimeter	Phoria	Stereoscopic Vision	
		L Ext. '04-1-3		local	straight	eso. 2Δ	Concrete pictures some perspective	
No binocular perception		L Ext. '05-5-29 L Sup. '05-10-14	tenot. central	local local	L hypertropia straight			
Amblyoscope		L Ext. '06-3-27 R Ext. '06-5-15	tenot.	local	straight straight	15Δ L hyper. 2Δ	medium	
Control reading Post-operative		R Ext. '06-10-13 R Int. cap. '06-10-28	tenot.	local local	exotrop? ° straight	eso. 7Δ	partial	
Con		I		general				

hoping that others would follow the example so that one might be able to decide the relative value of different methods. Until this is done it is impossible for the earnest truth seeker to decide which of the various methods of advancement is the best. In this series the greatest effect of one operation without tenotomy was 30°; more often 15° to 20°. This variation is mentioned by Landolt and Meller.

Landolt says: *"No true clinician attempts to determine the effect of a muscular operation with mathematical accuracy, for in addition to the variations in the insertion and the degree of shortening of a muscle, the action on the eyeball must be considered from still a number of standpoints. It is therefore not possible to say that the tenotomy, or the advancement or the shortening of a muscle, causes a change in the direction of the eye of so and so many degrees, nor does the degrees of deviation of the eye necessarily give the degree of resection or advancement of the muscle which is necessary for its correction."

*Archives of Ophthalmology, March, 1914.

Meller says:* "Still less accurate figures can be given here (advancement) than in the case of tenotomy. The variations in the extent of the results should not occasion surprise, and it would be extremely naive if we could believe that each millimeter of excised muscle will produce exactly the same degree of correction in every case, or that a certain degree of strabismus will be overcome by the excision of so many millimeters of muscle in accordance with an inflexible rule. A change of 30° in the position of the eye is the most that can be expected from an advancement; usually it is much less, and may be put down at 20° as an average in an operation with normal course.

"In the method which has been described, there are two means of influencing the effect of advancement — the excision of a piece of muscle, and the suture of the insertion in front of the original point of attachment. *The last plays a more important part than the excision.* If the operation is limited merely to the excision of part of the muscle, and the muscle again sutured to the original point of insertion, the effect of the operation will

*Ophthalmic Surgery, p. 96.

be slight. *Of decided importance is the approaching of the new point of insertion of the muscle toward the limbus.*"

Treatment of Antagonist. — The author pleads guilty to having somewhat frequently tenotomized the antagonist when the effect of one advancement proved insufficient. It is so easy at the time of removing the suture to "get just a little more" without requiring the patient to undergo another advancement, and he has had few occasions to regret it.

Worth:* "I do not now perform tenotomy of any ocular muscle, save in quite exceptional cases. I formerly considered tenotomy, combined with advancement of the opponent, to be safe, but have had reason to modify this view. I endeavor to see my old squint cases at intervals of two or three years, even after all need for treatment has ceased; and it is usually not until several years have elapsed that I have had cause to regret the performing of a tenotomy."

Landolt told us this in 1900:†

"*Since it is not possible to foresee the ultimate effect of any strabotomy, we advise not to perform*

*Worth: *British Medical Journal*, Nov. 4, 1911, p. 4.

†Landolt: "System of Eye Diseases," Norris & Oliver, Vol. IV, p. 119.

both operations at the same sitting, but to wait the effect of the double advancement before practicing a tenotomy."

We are now following his advice.

The Attachment of the Tendon After Advancement.— At the St. Louis meeting of the A. M. A., 1910, E. C. Ellett said, in discussing Dr. Hulen's paper: "It has been demonstrated recently that in these operations where the tendon of the muscle is advanced you do not advance the true attachment of the muscle at all. The muscle attaches itself solidly to the globe from the point of the new attachment clear back to where it was cut from the sclera, and the true new point of attachment is the old point of attachment. You have merely shortened the muscle. If that is true, and it has been demonstrated anatomically to be true, it seems to me a great deal would be gained by abandoning this scleral anchorage altogether and fastening the stump of the cut muscle at the site of the original insertion, which is very much easier to do."

Having been a follower of Landolt and Worth, the question was submitted to them, and their replies are published with their consent:

"4 Rue Volney, Paris,
August 21, 1910.

"In answering your very kind letter of the 4th inst. I may say that, since I have practiced advancement of the muscles of the eye (my first publication on this subject was in 1878), I have had abundant opportunities of studying how the muscles become attached to the globe after advancement as well as after tenotomy. . . .

"When the so-called advanced muscle becomes re-attached to its old insertion, there must be an error in the operative procedure, and a favorable result cannot be expected. Such cases furnish, of course, no argument against my method. It is as if some one would argue against cataract-extraction who does not succeed in getting the lens out of the eye. . . ."

Mr. Worth's testimony is as follows:*

"After an ocular muscle has been advanced, the question of whether it becomes attached to the globe only at its intended point of attachment, or whether it becomes glued down to the globe for a considerable part of its length, will depend partly upon the kind

*Personal Communication, April, 1914.

of operation which has been performed, and partly upon the skill of the operator. In my advancement operation, a most important point is that I do not isolate the muscle and I endeavor not to disturb its relations more than is absolutely necessary. After the advancement, the *muscle becomes attached to the globe at the designed point of attachment and nowhere else.* In the very large number of advancements which I have performed by this method during the last eighteen years, there have been some errors of judgment which I have had the opportunity of rectifying by a second operation. When I have had to increase the effect of the former operation, or when I have had to set back my new attachment a little on the globe on account of having produced too much effect, I have always found the under surface of the muscle is free from attachments, as is the case with a muscle which has not previously been advanced. But, apart from this direct evidence of dissection, any man of experience must know the difference between an efficient advancement of a muscle and mere shortening of the muscle; the eye will rotate to a certain extent in the desired direction, but

the power of the muscle is not increased. Its range of action is often decreased, and I have seen many relapses."

Naturally the opportunities for investigating these points are not many.

Case No. 58112, L. Exotropia 30°, L. Int. was advanced under general anæsthesia; result = exotropia 10°. Two years later, under local anæsthesia, same muscle was advanced again. Firm attachment was found close to cornea, but it did not extend back more than 3 mm.

Stevens* calls special attention to "the importance of the capsule in modifying and maintaining the effects of surgical operations upon the eye muscles." The excellent results which Fox can demonstrate with his conjunctivo-capsular resection without disturbing the muscle teach us not to ignore the capsule. Every operator has frequently observed a very slight development of muscle fibres when the advancement forcep is turned over. Advancement of the separated tendon cannot be as effective as when conjunctiva and capsule are included. Resection or tucking without advancing the insertion must be

*Stevens: "Motor Apparatus of the Eye," 1906.

still less effective. Since our experience bears out the statements of Landolt, Meller and Worth, that one need not fear over-correction if the antagonist be not tenotomized, we feel that it is a mistake to fail to *advance all the structures, conjunctiva muscle and capsule.*

CHAPTER IX.

POST-OPERATIVE FUSION TRAINING.— THE DIFFICULT CASE.— THEORIES.— PSYCHIC ELEMENT.— THE CHOICE OF CARDS.— FUSION AMPLITUDE A VALUABLE RESERVE.

CONCERNING post-operative training the latest word which we have seen from Landolt is as follows:* "Immediately after the definite removal of the dressing, exercises for binocular vision must be begun. The patient operated upon for convergent strabismus will wear spectacles to correct the total hypermetropia and astigmatism, if it be present. The one who has been operated upon for divergent strabismus will be allowed, and even urged, to look at objects at close quarters, for the purpose of exercising his convergence. All patients should go thru exercises intended, firstly, to perceive simultaneously the visual impressions of both eyes, then to combine the true impressions so as to give rise to the sensation of the third dimension."

While it is perfectly true that a majority of the previously strabismic eyes are extremely amblyopic, nevertheless to rest

*Bowman Lecture Trans. Ophthal. Soc. Vol. XXXI, 1911.

content with a cosmetic success, without attempting to cultivate binocular vision, is not discharging one's whole duty to one's patient. Even tho the vision of one eye is quite defective, there may be developed a degree of fusion which is not only quite useful to the patient but is the best possible prevention of a recurrence of the heterotropia. Some with vision as low as .2 can be taught to appreciate relief, a true binocular single vision.

If a true antipathy to fusion exists, it is useless to persist. It is quite possible that such cases are due to a complete, instead of partial, decussation at the chiasm — a reversal to an ancestral type. Worth thinks the alternating cases fall into this category; but the rule is not invariable.

If the vision of both eyes is good, the change from heterotropia to heterophoria may induce all the symptoms of incoordination by the increased difficulty of suppression of one image. When one considers the complexity of the co-ordination required for binocular single vision, it is hardly conceivable that a surgical operation could change a heterotropia to orthophoria.

Illustrative case, No. 11819, April 4, 1916. Patient a lady aet. 28, with symptoms of headache, feeling of strain in the head and neck for fifteen years; at present not able to read ten minutes without great discomfort.

From her former oculist the following history was obtained:

"Mrs. X's condition Feb. 24, 1915, was as follows:

R. V. 6/5 Cycloplegic: R. V. 6/6, with +.25 D. S. ⊃ + .25D Cyl. 90° = V 6/4

L. V. 6/6 Cycloplegic: R. V. 6/10, with + .62 D. S. ⊃ + .50D Cyl. 90° = V 6/4.

16$^{\Delta}$ exophoria distance, 20$^{\Delta}$ exophoria near. 3$^{\Delta}$ right hypophoria. A full correction was ordered for constant use, and various orthopic exercises tried, with no benefit to the heterophoria, and on April 20th I performed a Worth's advancement on the left internus with perfect immediate result. The exophoria gradually recurred, however, with the same intense asthenopia as before, and a complete tenotomy of the left externus was performed June 26th to correct an exophoria of 18$^{\Delta}$. This gave relief for about a month, when the symptoms began to recur. She was then

given 5^{Δ} prisms over each internus, with 2^{Δ} prism base up right.

Mrs. X has been a puzzling case, I must confess, and I have come to the conclusion that her trouble lies in deficient fusion impulse. On more than one occasion since the second operation there was lateral orthophoria with the Maddox rod test, for a minute, the visual axes then gradually diverging until 10^{Δ} or 12^{Δ} prisms were necessary to fuse the images. There is a strong neurotic element, and she suffered inordinately both at the operation and afterwards."

Examination:

Under atropine

Right $+.25 \bigcirc +1.12$ C $90°$V $=1$.
Left $+.50 \bigcirc +1.12$ C $80°$ V $=1$.

Exophoria 10^{Δ} Prentice Williams Color Phorometer
Left Hyperphoria 2^{Δ} Prentice Williams Color Phorometer
Adduction 16^{Δ}, Abduction 16^{Δ}
Binocular vision tests:
Stereo $+10 = 65$ mm., Suppress L F_4, E_1 O.K.
"ONE" 30^{Δ} fuse 15^{Δ},2^{Δ} L Hyperphoria with B_3.

Since hyperphoria often disappears as the convergence increases, the vertical prism was omitted and she was given

Right —.25 ⌔ +1.00 C 90°
Left +.87 C 85°

Treatment;

For home work with stereoscope series C, F & G were used at first and patient came to office three times a week. After six visits she was given control device and told to begin reading a few minutes at a time. At this time the stereo-convergence with C_7 ON NE was only 40$^{\Delta}$, showing slow progress. In fusing loose prisms the left eye would diverge without patient recognizing the diplopia, showing the importance of stereoscopic duction. At the eleventh visit orthophoria by binocular tests, but exophoria 9$^{\Delta}$ by cover test. Left hyperphoria $2\frac{1}{2}^{\Delta}$, same as before treatment.

Stereo-convergence 90$^{\Delta}$ with C_7, loose prisms not tried, as the tendency to let one eye diverge was not cured. Could fuse H & I series with o. u. Pr. 5$^{\Delta}$ B out in stereoscope. As the hyperphoria persisted prism $1\frac{1}{2}^{\Delta}$ base down was added to left.

Symptoms. — April 22nd, *i. e.*, two weeks after beginning treatment, "no pain in eyes, has read one-half an hour at a time." April 29th, "has used eyes most all day, doing exercises, reading and sewing."

As patient lived in a distant city, she was allowed to go home, but she was given very definite homework. The control device was changed from the single to the three prong, the 5^{Δ} prisms were increased to 10^{Δ}, and exercises varied by the use of a couple of dozen marked stereographs. Not seen again until September 6 (four months), when she reported that she could read two or three hours with the three prong control, and sew and write as long as she wanted to with the one prong control. Exercises had been kept up but at increasing intervals. Orthophoria by binocular tests, Exophoria 10^{Δ} by cover test. Stereoscopic convergence 90^{Δ} with C_7.

From the above case it is evident that post-operative training is carried out in the same manner as the pre-operative. If controlled reading is possible, the constant use of the device for *all* near work is most valuable. This should be continued for many months, possibly a year.

THE DIFFICULT CASE.

It was stated in Chapter IV that the successful cases averaged ten to twelve treatments. Just when one should give up and call the case a failure is a matter of individualization. One patient, who had made practically no progress in eleven treatments, at the twelfth visit seemed to "catch on," showing the cumulative effect of the previous effort, and in four more sittings fused over 100$^{\Delta}$ both with the stereoscope and loose prisms, with complete relief of symptoms. When seen again after six months there had been no loss of power.

If, as one watches the eyes over the stereoscope, and this should always be done, one eye is seen to turn but little, the prism before the other eye is turned to zero and the whole amount exhibited before this "lazy" one. This has never failed to stimulate the convergence. This will always be the eye which is suppressed in the test with series F & G.

Theoretically the accommodation should be at rest, and this is accomplished when the emmetropic eye looks through a +10. at a chart 10 cm. distant, but with a case which fails to converge when the spheres are sepa-

rated, it is justifiable to utilize the accommodation to start the habit. This is done by substituting +7. or +8. spheres. One should also try the Gould exercise, which consists in putting in a trial frame, prisms base out, 10$^{\Delta}$ more than the patient can fuse. The eyes are closed while the prisms are adjusted. The room is darkened, and when the eyes are opened he sees a small electric light, like a candle, about one foot away. This he fixes, as shown by the reflections in the middle of the pupils. The candle is then carried to the other side of the room. If the prisms are not too strong, the hold obtained by means of the convergence *plus the accommodation* is maintained and no diplopia results. The eyes are closed, and when again opened the candle is two feet away and is again carried across the room. The next time the candle is four feet away and the distance is doubled each time. If the candle can be fused when it is across the room when first seen, 5$^{\Delta}$ to 10$^{\Delta}$ more prisms are added and the exercise repeated. This is continued until diplopia results. Until one is sure the patient will not suppress one eye and thus fail to recognize the diplopia, it is well to have the assistant watch his eyes.

This exercise is to be used but a few times as it does not lead to any permanent gain in convergence, and often produces quite a strain, but it is justifiable as a means of starting a slow case. Another means of overcoming a persistent suppression of one eye with the stereoscope is to put a +12. sphere before the favorite eye. This blurs the picture before that eye and thus coaxes the use of the other. In the home exercises the patient smears a film of soap on the stereoscope lens before the favorite eye, just enough to make the vision better with the suppressed eye.

THE PSYCHIC ELEMENT.

A highly developed fusion faculty, with good amplitude, is the ideal concomitant of perfectly corrected refraction. In correcting or relieving heterophoria, the first essential is the development of a refined fusion sense, if such does not exist, or in making habitual its employment in the psychic interpretation of two retinal images.

The power of a muscle depends not alone on its own physical properties, such as size, nutrition, place of attachment, etc., but also on the strength of the nervous stimulus which

excites its action. In discussing this subject, in 1902, the writer made the following statement: "The rapid development of adduction, which is so often obtained by this so-called 'gymnastics,' strongly suggests that the gain is not a muscle hypertrophy, but an increase in innervation, either in the responsiveness of the end organ in the muscle, or the convergence center, or both." In the educational treatment of tabes the incoordination is overcome by teaching the patient to gauge his motor impulses by the eye, in lieu of the normal sensory control. Repeated artificial contractions of the internal rectus (the ciliary remaining relaxed) establish a habit of increased action, so that it no longer lags when the impulse to converge and accommodate is felt. The co-ordinating center may also be taught to better appreciate the advantages of binocular perspective. This is no special pleading, but is analogous to other sensations. The pianist makes his fingers educate his brain, that the brain may do better work with the fingers. Tasks consciously performed are in time relegated to subconscious control. If this interpretation of muscle gymnastics be accepted, it is evident that the first indication

is to teach the patient the fascination of true binocular fusion. Just as in the ordinary prism exercises, with the eye fixed on a distant point, the aversion to diplopia is an incentive to increased muscle action, so here the fused image becomes an anchor. With the eyes fastened on a fused image, made up of half pictures, one strongly resists an impulse which tends to pull it to pieces. *The decentering of plus 10. lenses is a subtle means of insinuating such an influence.*

In all exercises of this sort there is a psychic factor which should be utilized. Whether there is or is not a fusion *center*, there is a fusion faculty which can be cultivated, in proportion to the patient's attention and co-operation.

To do this, while the phoro-optometer stereoscope is being used, the patient should be repeatedly directed to fix his attention on the red N of the "ONE" card. To help him do this he should be told to analyze the color, to decide just what shade of red it is, or to fix his attention on the oblique line of the N. Other expedients will suggest themselves if the importance of this fixation of attention is appreciated. No distracting

sounds should be tolerated; in fact, there should be no third party in the room.

The patient should also be aware that the oculist is thinking only of him, and whenever any gain, however slight, is evident, as one watches the eyes over the stereoscope, some word of commendation should be volunteered. If no such commendation should be justified, he should be encouraged by the suggestion, "Now try a little harder this time."

THE CHOICE OF CARDS.

The difference in the holding power of diferent cards has been mentioned. Formerly C_8 of Javal was used. This consists of separate letters L and F, the fusion of which gives E. After considerable experimenting the author devised the ON NE, the two N's printed in red, and believes this possesses the greatest holding power of anything yet produced. In the first place the word spells O N E, and when disjointed the ON NE is meaningless. More letters are superfluous and detract from fixation. That there is a subtle suggestion in this, one can easily verify in the following way: After the card ON NE has been used on several occasions, if the

prism is arranged so patient sees arrow over 6 of the card B_1, and if then C_7 is dropped into the clip, the patient will often be confused, but will be immediately relieved if 5^{Δ} or 10^{Δ} more of prism be turned up. This shows that while conditions were exactly right for easy fusion of C_7, the instant that card appeared he immediately remembered what it had previously required and involuntarily converged his eyes more than was necessary. It is advisable to experiment with other cards, especially if the case is not progressing well.

FUSION AMPLITUDE A VALUABLE RESERVE.

In convergence insufficiency we are dealing with an incoordination of convergence and accommodation. The nerve impulse sufficient to secure accommodation is insufficient for convergence. To relieve this and to restore co-ordination, it is necessary to incite, associate and to make habitual a greater degree of convergence with a given amount of accommodation. For this reason it has always seemed to the writer that exercises which bring into play the accommodation as well as the convergence are illogical; *e. g.*, dot ex-

ercises at the reading distance or candle as used by Gould.

With eyes fixed on a distant light, it is assumed the accommodation is zero, but this is difficult to verify. When emmetropic eyes looking through plus 10. lenses see clearly at the focal distance, 10 cm., we have proof that accommodation is relaxed, and it is under these conditions that we secure a very abnormal amount of convergence. To a certain extent the same is true of the home use of the stereoscope with additional prisms in the clips.

With perhaps one-half of one's successful cases orthophoria will be secured, with the other half the heterophoria will be reduced, but the patient will have secured such a superabundance of amplitude that he is able to overcome the wrong tendencies automatically without discomfort.

Not infrequently one sees a patient who has learned to overcome strong prisms who is still uncomfortable, because his fusion faculty is poor and co-ordination for small objects, like types, inexact. One can understand that a man might be able to make a long jump, and yet not able to land on an exact spot less than

his full distance. This ability to *land exactly* is what perfect co-ordination requires. The stereoscopic training of convergence accomplishes just this exactness. Stereoscopic convergence reproduces the conditions required for perfect binocular single vision. *Finally, this is best stimulated by the decentration of spherical lenses.*

CHAPTER X.

HAITZ BINOCULAR LOCATION OF SCOTOMATA BY MEANS OF THE STEREOSCOPE. — THE ADAPTABILITY OF THE PHORO–OPTOMETER STEREOSCOPE FOR HAITZ AND BISSELL CHARTS. — THE LLOYD COMBINATION CHART. — DISTINCTION BETWEEN DEGREE AND PRISM DIOPTER. — THE STEREOSCOPIC TANGENT OF ONE DEGREE. — RADIUS TO BE MEASURED FROM NODAL POINT.

HAITZ BINOCULAR LOCATION OF SCOTOMATA BY MEANS OF THE STEREOSCOPE.

ABOUT five years ago Dr. Arnold Knapp called the author's attention to the Haitz charts. When these were obtained from Emile Sydow, Marien Strasse 10, Berlin, much difficulty was experienced in getting at the author's exact meaning from the original instructions.

With the aid of Prof. Marshall L. Perrin, Professor of Germanic Languages of Boston University, these were translated, and some of the technical difficulties corrected by Dr. Ernst Schlack, of Brooklyn. This system proved to be of such inestimable value that

the translation was published December, 1916, in the *Journal of Ophthalmology, Otology and Laryngology*, and is here reproduced by permission.

INTRODUCTION.

(Translation.)

Although since the introduction of the perimeter by Aubert and Foerster the investigation of the field of vision has in general attained a high degree of exactness, yet until very recently it was not possible to determine central defects with sufficient accuracy. For the discovery of the smallest central scotomata there are, to be sure, a number of special methods and instruments (scotometers) recommended, but with regard to the fixing of the larger central scotomata, or those varying eccentrically, the oculist must confine himself to the usual perimetric method. Results obtained in this way are naturally deficient, inasmuch as there is no dependence upon the fixation, and the results of the observation give only an approximate idea of the size and form of the defect in question. In no case is it possible to perceive, with any degree of assurance, comparable results taken at short intervals, whereby to note the progressive

nature of the disease. This is so much the more important for the oculist, as it is from just such repeated observations and their relations to one another that he can obtain reliable data concerning the progress of the disease or the effect of his treatment. Therefore, it was an important occurrence when Schloesser brought out again a forgotten binocular method introduced by Hirschberger for other purposes. Schloesser showed that with the help of this method central defects could be much more definitely determined than by the usual monocular method. For by leaving the second eye open and using it for fixation, the weaker eye with the central defect is able to maintain a more constant position. This method, which was first adopted, and the only binocular one made use of, was, however, subject to a number of inaccuracies which limited its use materially. It is, therefore, better in the investigation of the central part of the visual field to make use of another binocular method, which has been introduced by me, viz.: the stereoscopic. It is true that this latter is adaptable only for the field within 0° and 10°, although in case of emergency it can be extended to 20°. It is, however, most

exact in this limited field, especially because there is sufficient assurance that in spite of a possible heterophoria the eyes maintain their normal binocular position. The binocular method of investigation by means of the stereoscope is especially to be recommended in all forms of central defects where the limits are entirely, or for the most part, within the 10° zone, and, secondarily, when the border (of the scotoma) approaches the intact point of fixation, as in hemianopsia, in monocular half sight, and with sector shaped defects, etc. In this last case the stereoscopic investigation is rather secondary and confirmatory, — a more exact determination of results obtained by the ordinary perimetric tests.

The examination of the zone of 10° is undertaken with the Kampimeter charts Nos. 2 and 1, which I hope will soon become an indispensable part of an oculist's outfit.

Each portfolio contains a set of scotometer charts. The discovery of the smaller central blind spots is made more quickly with these than with the Kampimeter charts. They have advantage over all other scotometers in that by reason of their binocular nature they force the defective eye, with peculiar

constraint, to maintain the central position.

I believe that these scotometer charts will have a special advantage when used for a great number of observations at the same time, particularly in the examinations of the employees of the railroads and the navy, which are absolutely necessary from time to time. For here the chief purpose is the discovery of possible acquired defect of central sense of color. It is extremely important to discover such defects in their incipiency, as they are for the most part of a progressive nature, and a person in question might, if this is not discovered soon enough, be the cause of great disaster. Special attention may well be given to these conditions among marines who are accustomed to indulge in periodic excesses which may produce neuritis optica. It has been well proved that simply by the smoking of a strong cigar one can acquire a temporary red-green-scotoma.

Advanced cases, of course, could not escape the oculist under methods ordinarily used, but these incipient color scotomata can very easily be overlooked. The deficiency in acuity of sight is at first very small, and if the investi-

gation is made in the daylight the oculist would be inclined to refer the apparent deficiency to an insufficient light, whereas such a patient really sees better under these conditions. In the test which recently has been made obligatory in the Prussian railway with the Holmgreen method, this disease has in no case been found. Incipient cases have not been discovered, and in such cases the binocular stereoscopic color scotometer will certainly prove to be of the greatest value, because in testing malingerers it is possible to completely "rattle" the patient with the stereoscope, by the alternate covering of the eyes or by turning around the chart and other tricks.

It is possible to modify the investigation somewhat by the introduction of smoked glasses according to the method of Everbusch's test for signal lights.

DIRECTIONS FOR USE.

(Translation.)

General. — In order not to burden the oculist's equipment with further apparatus, I have adapted my charts to the Holmes, so-called American, hand-stereoscope, which is much used for strabismus and is to be found

everywhere. It is well fitted in general for our special purposes. One might perhaps blacken the wooden portions which are visible to the patient, and in case the slide for holding the pictures is too brilliant it might be wrapped in dark grey woolen.

It is very desirable, however, to find out in the first place the strength and position of the half lenses, inasmuch as the models which are to be obtained are unfortunately subject to great variations in these respects. Of course, for several reasons, the charts are to be placed at such a distance from the half lenses that the whole, or at least the zero points of both sides, shall lie in the plane of the foci of the lenses. Consequently, the charts had to be adapted to lenses of certain strength and distance.

The stereoscopes which are furnished the oculists by the larger firms have lenses which are ground with a radius of curvature of 20 cm., and the optical centers lying in the base are about 8½ cm. apart. These are the conditions which I have taken for normal in the arrangement of my charts. Such lenses have a focal distance of 19 cm. (= 5¼ diopters). Inasmuch as the focal distance is reckoned

from the side of the lens turned to the slide, the latter is consequently to be brought to such a position that the middle of both pictures stands at about 18.8 cm. from the bottom of the side of the lens turned toward the nose. This normal position of the slide it is well, to start with, to mark with a line on the sliding track.

Lenses with 5 diopters as well as those with $5\frac{1}{2}$ can also very well be used. In the latter case, that is, with the focal distance of 18.2 cm., the above mentioned distance between the zero point of the chart and each of the lenses should be made somewhat smaller, say, 18 cm. In case of the charts Nos. 1 and 2 the interval between the lines which otherwise would correspond exactly to the visual angle of 1° becomes .16 mm. too large. At the 10° point the correction would then be 1.6 mm. or about one-half a degree.

If, however, the lenses are only 5 diopters, that is, a focal distance of 20 cm., then it is necessary to act according to the distance between the centers of the two lenses. If this be relatively small, say, about 8 cm., then the charts are to be put as before in the plane of the axis, but the distance should be

taken 1 cm. longer, that is, 19.8 cm. The correction then to be made is exactly the same as in the former case, only in the opposite direction. That is to say, the distance between the lines marking the degrees appears .16 mm. too small. If, however, the distance between the (centers of the) lenses seems to be relatively large, say, 9 cm., then place the charts in the normal distance given for the lenses $5\frac{1}{4}$ and the observation takes place with slight accommodation. The inexactness arising from this is negligible.

Greater variations in the strength of the lenses than those mentioned are not admissible. One need not be so particular, however, with regard to the distance between the lenses, since slight differences of the eyes, especially in the direction of convergence, can, as is well known, be easily overcome. Most persons whose accommodation is weak usually perform the act of convergence easily.

If in the manner directed the charts are observed without accommodation, then the size of the degrees as well as the distance between the corresponding points of the two pictures are independent of variations in the pupillary distance, and also of variations in

the distance of the eye from the stereoscope lenses. For that reason it is entirely unnecessary to make the lenses adjustable.

In every case it is necessary first to make a test of the central acuity of vision, as well as of the extrinsic muscles, before an examination of the field of vision with the stereoscope. Ametropic persons should wear their distance glasses. In the case of axial ametropia, if the correcting glass is at the anterior focal distance from the eye (which in the reduced eye is 15 mm.), as is frequently the case, as a matter of fact, then the size of the degree appears nevertheless normal. If it does not stand exactly in the anterior focal point, or if it does not correct the ametropia, then temporarily the size of the degrees intervals is somewhat influenced. But these errors are never great, and their significance is entirely negligible, in a series of observations made and compared, providing all these observations were made with the same correcting glass. It is advisable in each case to notice the strength of the glasses.

The healthy eye, which is used for the sake of fixation, must naturally have sufficient acuity to be able to distinguish properly the

mark of fixation, and both eyes must be able to distinguish at least parts of the corresponding outlines.

Owing to a peculiar construction of the fixation points (of the charts), which I will designate as negative, it is possible even then to use the second eye for fixation, although it may itself be affected with a central scotoma with reference to absolute white. With these Kampimeter charts this may be even as great as one-half degree without damaging the accuracy, for it then occurs just in the central hole. A larger central scotoma of the second eye lowers naturally its worth, but even then the stereoscopic investigation will in many cases give far more exact results than the monocular, for the peripheral outline itself acts as a great circular fixing element.

During the investigation both eyes must be held in their normal central positions. Patients with manifest strabismus are consequently excluded altogether from such examinations. Persons with latent strabismus of medium grade are for the most part good subjects for stereoscopic examinations, and always if it is possible for them to accomplish a continued fusion by means of the common

outlines which have been arranged just for this purpose. By the doubling of these outlines a deviation of one of the eyes is made manifest, while the control points on the two pictures expose a possible case of monocular exclusion. Only that latent strabismus is here considered which exists for distance, tested in connection with properly centered distance glasses. This is best measured at a distance of 6 m. (Maddox rod).

After looking for a long while through the stereoscope, it is not seldom the case that portions of the picture suddenly disappear and immediately re-appear. These passing defects are of homonymous nature and purely functional, and must not be mistaken for organic. Only the boundary test, never the fixation zone, will be affected by fatigue of patient. For that reason it is well never to allow the patient to look too continuously through the stereoscope, but to make pauses while one is taking notes. If the oculist is ever in doubt whether the defect is functional or organic, then he should cover for a moment the eye which is being examined, for when it is uncovered a functional defect will immediately disappear.

THE STEREOSCOPIC KAMPIMETER.

(*Translation.*)

Charts 1 and 2 serve for the observation of fields of vision lying inside of 10°. The examination takes place, as usual, by means of a movable object. The division of the degrees is such that distance between them amounts exactly to a visual angle of 1° when the charts are in a normal position, and this side of the chart is always to be placed before the eye to be tested. As a rule, the middle of the figure which shows a large hole of one-half degree is to be fixed. If one wishes to extend the examination as far as 20° from the fixation point then in chart No. 1 he can fix as far as the end of the meridian.

Chart No. 1 is especially adapted for crude tests, therefore, one should use generally chart No. 2 by means of which finer details, such as small extensions and the like, can be better found. The marker is carried just parallel to the lines and, of course, in both systems (of lines, horizontal and vertical) from the outside toward the *zero meridian.* It would be wrong to pass the object to start with over all the lines, not only on account of wasting of time, but because it would occasion an

early fatigue on the part of the patient. It is best, therefore, at first to make observation only for 0° (vertical, Knapp), 2½° and 5°, etc., and let the determination of the finer details come afterward.

Inasmuch as the objects and the holders which are usually employed with the perimeter are much too bungling for our examination, I have had special ones made for this purpose. In each case a holder as fine as a knitting needle carries an object of 1½ and 2 mm. in size, respectively. The first is for use in the zone between zero degrees and 5°, and the latter is to be used between 5° and 10°.

One should, if possible, avoid holding the marker over either one of the corresponding outlines, because that would occasion incoordination (struggle of equality) and monocular exclusion. If one wishes to examine particularly the 45° meridian, then carry the object along the side of the white radius and not directly over it.

And, furthermore, never let the holder come within range of the second eye, for it would then be seen double and cause confusion. Accordingly when carrying the object from the

nasal side toward the middle it must be held in a perpendicular position.

I very strongly advise against recording the results upon the usual perimeter charts, for their unit is much too small for these examinations. By use of chart No. 1, to be sure, it is possible to make it all right by letting the 10° interval of such a chart (the perimeter) count for a 1°. Nevertheless, it is best, and in use of chart No. 2 essential, to record the result by the help of a rubber stamp upon the back side of the chart which is used for the recording of the peripheral boundaries. (Such stamps have been prepared according to my directions and are to be had from the shop of Carl Bofinger, Stuttgart, Gutenbergstrasse.)

THE STEREOSCOPIC SCOTOMETER.

(*Translation.*)

Charts from 3 to 7, inclusive, serve for the determination of the smallest central scotomata. The central point of 1¼ mm. is seen under a visual angle of a little over one-third degree.

It is desirable, at the start, to cover the eye to be tested by holding a piece of paper in front of the stereoscope lens, and then to tell the patient to find the middle of the picture

with his other eye. Then suddenly uncover the first eye and ask the patient what the color of the middle point is.

Very delicate central variations of shades of colors may be well observed by holding near the fixed central object a movable one of the same kind, or if it is a case of one-sided scotoma one may turn the chart around (*i. e.*, let patient fix the colored spot with eye not undergoing test).

The somewhat differently constructed chart No. 3 is to be used in the case of less intelligent patients, when it is quite possible to determine by means of chart No. 4 whether it is a case of an absolute or only a relative white scotoma.

(*End of Translation.*)

THE ADAPTABILITY OF THE PHORO–OPTOMETER STEREOSCOPE FOR THE HAITZ, BISSELL AND LLOYD CHARTS.

In using Haitz charts the writer at first followed Haitz's instructions, using an ordinary Holmes stereoscope, marking on the same the distance at which chart should be viewed. It was soon found that holding the stereoscope was tiresome for the patient, and quite unsteady. As constant use is made of

the phoro-optometer it was found much more satisfactory to make the stereoscope to order for each patient; o. u. +5.25 is used with the chart at 19. cm. In the ordinary use of the phoro-optometer stereoscope o. u. +10. is employed with the cards at 10 cm. This makes each prism dioptre ($^{\Delta}$) = deviation of 1 mm. With o. u. +5.00 at 20 cm., each prism dioptre ($^{\Delta}$) = deviation of 2 mm. With the B_2 card the natural fusion distance is determined, and sufficient prism introduced to make lines cross at 8, since Haitz charts have a separation of 8 cm. For example: should the red line cross at 5 this means that 5 cm. is the natural fusion distance. To secure the crossing at 8, fifteen dioptres more is required, since 30 mm. more deviation is needed, and at 20 cm. each prism dioptre = 2 mm., 30 ÷ 2 = 15. If the patient happens to converge, more prism will be needed, the exact amount being determined by turning the rotary prisms. The patient should wear his refractive correction, and if he be presbyopic, his reading glasses, or the necessary amount added to the o. u. +5.00.

The stereoscope is now ideal for mapping a central scotoma, and at the same time it has

been demonstrated that the patient has binocular vision sufficient for the test. Since visual acuity is often poor and fusion faculty of low grade, it was found that the lines of the B_3 card were too fine to be easily seen by many patients. A modification of B_3 with heavier lines has, therefore, been drawn upon the back of the Haitz chart.

BISSELL BLIND SPOT CHART.

In 1916 Dr. Bissell of Rochester, N. Y., published his chart for measuring the blind spot by the Haitz principal of stereoscopy. In using this, it is necessary to get a wider field. This is easily obtained by commencing with the o. u. +5.00 decentered out 5 or 10 mm. wider than the patient's P. D. and substituting for the revolving prisms, after the necessary amount has been determined, plain prisms from trial case. This increased distance of the lateral part of the chart changes the perfect correspondence of squares to degrees of the arc, but if one wishes to be more exact the chart can be bent by having a third support, so that the ends and the centre will be the same distance away.

THE LLOYD COMBINATION CHART.

Lloyd's slate, described in the *Ophthalmic Record*, August, 1917, is a combination of the Haitz and Bissell charts, and, therefore, suffices for both purposes. The color of the cross lines is much more subdued than the previous charts of American manufacture, and is, therefore, less confusing. If one is not

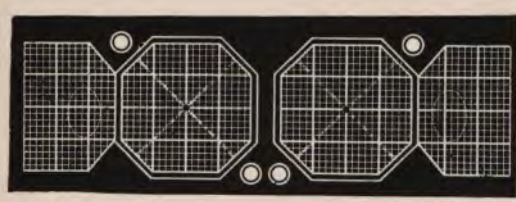

FIG. 30.— LLOYD SLATE.

fortunate enough to possess the original Haitz, he will find this a decided improvement even for central scotomata, while for the blind spot measurement it shows at a glance the relation to the macula, and the normal area according to Gradle.

The writer suggested to Lloyd and Bausch & Lomb the making of record slips duplicating the slate. These suffice for recording either central or para-central scotomata or blind spot measurements, for one or both

eyes, and always maintain the relative positions. One may mark on the slate with chalk, as Lloyd suggests, and transfer the record later, but it has been found quite satisfactory to have the assistant stand behind the patient — slip in hand — watching the point reached by the object, when the patient first sees or first loses it, and mark it immediately on the slip. In this way the permanent record is finished as soon as the test is completed.

Those who do not use the phoro-optometer will probably prefer to get the special wide angle stereoscope, but the method described does not necessitate the patient's moving from his chair, dispenses with a new instrument, and gives one a knowledge of the patient's fusion faculty, *which should be investigated before attempting the test.* The only expense involved is the central aluminum screen, the cost of which is trifling. Moreover, the writer still lives in hopes that more of his colleagues will recognize the value of the phoro-optometer stereoscope in fusion training and the cultivation of adduction. This adaptability for the Haitz, Bissell and Lloyd charts is an additional reason for the adoption of this wonderful instrument.

DISTINCTION BETWEEN DEGREE AND PRISM DIOPTRE.

The author must protest against the very common mistake of confusing the terms Degree and Prism Diopter. A degree (°) is 1/360 of the arc of a circle, and should be restricted to Perimetry, the measurement of Heterotropia and Stereoscopic Kampimetry. The unit of the prism diopter is a prism which deflects a ray of light 6 cm. at 6 m. Heterophoria is, therefore, measured in prism diopters.

According to Prentice's rule ("Ophthalmic Lenses and Prisms." 1917, p. 49), the prism diopter = tangent of 34′22″, figured as follows:

Tangent 1^{Δ} = .01
nearest smaller in table is Tangent 0°30′ = .008727
difference = .001273

nearest larger in table is Tangent 0°40′ = .011636
nearest smaller in table is Tangent 0°30′ = .008727
difference for 10′ = .002909

dividing the whole difference by difference for 1′ = minutes to be added to 30′.

$$\frac{.001273}{.0002909} = 4.37' = 4'22''$$

$\therefore$ Tangent 1^{Δ} = 0°30′ + 4′22″ = 34′22″

A 1° (degree) apex angle prism of glass, index 1.53, deflects a ray of light 31′48″ (Prentice: "Ophthalmic Lenses," 1900, p. 108), so that for the comparatively weak prisms re-

quired as spectacle lenses the two are practically the same, each deflecting a ray of light about ½° (degree). The prism diopter has become the universal unit, as it makes the fractional calculations so extremely simple.

THE STEREOSCOPIC TANGENT OF 1° (DEGREE).

Haitz has calculated his chart for +5.25, as this is the strength used in the standard stereoscope. At the focal distance 19. cm. this makes each square 3.3 mm. If o. u. +5.00 is used at 19.8 cm. he says each square is .16 mm. too small. This is easily figured by the principle of similar triangles, as shown by Peter.*

From tables we obtain Tangent of 1° = .017455.

1 : .017455 = focal distance : tangent required.

.017455 X 18.2 = .317681 cm. = 3.17681 mm. = tangent at 18.2 cm.
.017455 X 19. = .331645 cm. = 3.31645 mm. = tangent at 19. cm.
.017455 X 19.8 = .345609 cm. = 3.45609 mm. = tangent at 19.8 cm.
.017455 X 20. = .349100 cm. = 3.491 mm. = tangent at 20. cm.
.017455 X 21. = .366555 cm. = 3.66555 mm. = tangent at 21. cm.

*"Perimetry."

The result obtained above for 19. cm. corresponds exactly, but the difference between the tangent at 19. cm. and 19.8 cm. is .139 mm. and not .16. Since Haitz says the .16 mm. is "plainly negligible," this error is of no account. In order to be more exact the author has had made a very perfect pair of +5.25 toric lenses. This takes care of the central measurements at 19 cm., but the most lateral portion of the blind spot is almost 1 cm. farther away, that is 20 cm., at which distance the square is .17 mm. too small. If the blind spot has a lateral diameter of 5° (degree) (4°54′ Gradle), the whole error would be 5 X .17 = .85 mm. As the square is 3.3 mm. $\frac{.85}{3.3}$ = .25° (degree). That is, the blind spot would be mapped 1/4° (degree) larger than reality. This is, of course, too slight to be of any moment, but if one wishes to be more exact the chart can be bent by having a third support, so that the ends will be just the same distance as the centre.

THE POINT FROM WHICH TO MEASURE RADIUS.

There is one important item about which the author is unable to agree with the authorities, and that is *the point from which* this

19 cm. should be measured. Haitz says: "Inasmuch as the focal distance is reckoned from the side of the lens turned toward the slide, the latter is to be brought to such a position that the middle of both pictures stands at about 18.8 cm. *from the bottom of the side of the lens turned toward the nose.*"

Dr. Bissell* says: "The card carrier . . . should be just within the focal plane of the lenses, at 18.8 cm. In this position . . . the rulings of the card have a normal 1° angle if the center of rotation of the eyes is at 25 mm. from the *anterior* surface of the lenses." But he furnishes no means of obtaining this data. Presumably this means that the lenses should be 13 mm. in front of the cornea; and omitting the question of rotation, the 18.8 cm. is measured from the *anterior* surface of stereoscopic lenses.

Dr. Bissell refers to Mr. Max Poser of Bausch & Lomb as his authority, but notwithstanding his eminence as a physicist, it is impossible to regard this statement as satisfactory.

In constructing a wide angle toric lens it

*Exhibition of a special wide range stereoscope for the Haitz & Bissell Tests. Acad. Ophthal. & Oto-Laryn., Pittsburgh, Oct., 1917.

may be necessary to assume it will stand 25 mm. in front of the center of rotation, in order that the aberration may be corrected as the eye turns; but he has adopted Haitz's point from which to measure the radius, namely, the anterior surface of the stereoscopic lenses.

Moreover, he furnishes no means of determining the centre of rotation, and with a hooded stereoscope it is not possible to observe or measure the distance of the lenses from the corneæ, which is the only way *of approximating* the centre of rotation.

THE NODAL POINT.

To be exact, it seems to the writer that *the nodal point*, being the point through which pass all rays which enter into the formation of the image, must be the apex of both similar triangles *and must, therefore, be the point from which to measure radius.*

In the reduced schematic eye this point is usually given as 7.3 mm. for anterior and 7.6 mm. for posterior behind the cornea. The addition of a +5.25 will carry this point forward, the exact amount depending on the form of the lens and its distance from the

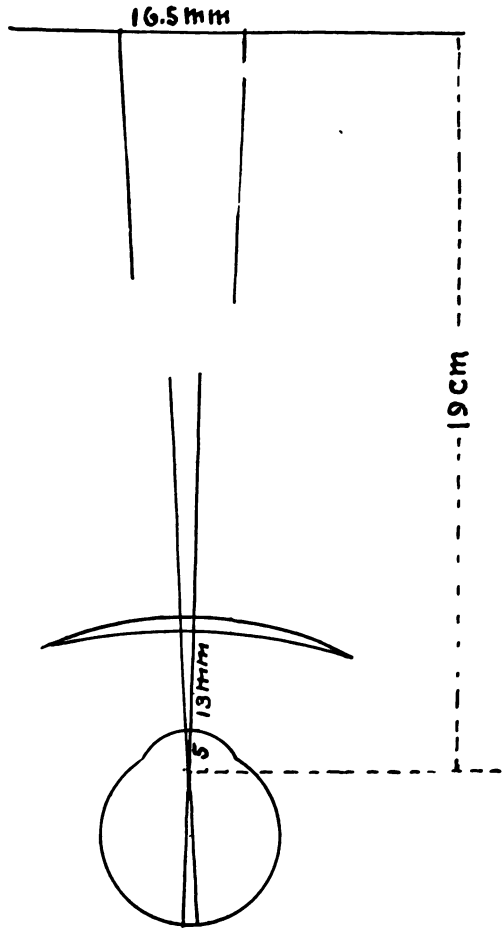

FIG. 31.— STEREOSCOPIC TANGENT OF 5° = 16.5 mm. (3.3 x 5). LENS —6.00 ⊂ + 11.25 13 mm. FROM CORNEA. LINES CROSSING AT APPROXIMATE NODAL POINT OF WHOLE SYSTEM 5 mm. POSTERIOR TO CORNEA. ACTUAL SIZE.

eye. If the lens be toric, with a base curve of —6.00 and an anterior curve of +11.25, and if it be situated at the standard distance, 13 mm., in front of the cornea, the nodal point of the whole system, lens and schematic eye combined, will be from 2 to 3 mm. farther forward, approximately 5 mm. behind the cornea.

Thus it appears that the nodal point is about 5 mm. + 13 mm. back of the stereoscopic lenses. This is practically 2 cm., so that the Haitz chart, with the 3.3 mm. square, should be placed 19 cm. — 2 cm. = 17 cm. in front of the stereoscopic lenses to secure the nearest approximation to a one degree equivalent.

Reference to the table on page 136 shows this error would make each square 3.66 — 3.31 = .35 mm. too small. This error would make the normal blind spot ½° too large, but is easily corrected by adopting 17 cm. as the distance of the chart from the back side of the stereoscopic lenses. *This is equivalent to measuring the radius from the nodal point.* But this calculation is for a schematic eye.

* "The nodal points differ in various eyes, according to their refractive power, and such

*Chas. F. Prentice, personal communication.

differences may even exist in two eyes having the same degree of ametropia, so that punctilious precision, as applied to their positions, does not seem possible of attainment.

"Besides, with the use of a stereoscope there is always an error of parallax incurred, due to the nodal point and the point of prism refraction not being made to coincide. This parallax is least when the eye is closest to the apex edge of the prism; and even were the cornea in actual contact with the prism surface, the nodal point would still not be at the point of refraction of the prism. Hence, a discrepancy between the plottings of the scale and the fundus will ever be present through the use of a stereoscope."

It is possible that the improved wide angle stereoscope may eliminate this error of parallax, but until the radius is measured from the nodal point, and the stereoscopic lenses are at a fixed distance, say 13 mm. in front of the cornea, it must be less exact than the phoro-optometer stereoscope.

Perimetry, with or without a stereoscope, does not correspond exactly with degrees of the retina. However, this limitation does not materially detract from the practical

value of stereoscopic perimetry, as the error need never exceed 1/4° (degree) if the 19 cm. be measured from the schematic nodal point of the combined system, and one would hardly presume to diagnose abnormality unless the enlargement of the blind spot were as much as 1° (degree). Moreover, the comparison of successive examinations made under similar conditions will show any change that may have occurred, that is, the error will be constant.

At the present writing the phoro-optometer stereoscope furnishes the most exact means of reproducing similar conditions. The lenses may be brought as close to the lashes as possible without touching, the pupillary distance of the lenses, and the exact amount of extra prism exhibited can be recorded.

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